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ENERGY CONSERVATION IN THE

ACQUISITION PROCESS

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EXECUTIVE SUMMARY

Defense energy has become a major budgetary, operational and policy issue as a result of the rapidly escalating price of oil and growing U.S. dependence on uncertain overseas oil supplies. Almost 90% of petroleum based fuel used by the Department of Defense is consumed by major weapon systems. Jet aircraft are the predominant users, accounting for 66% of consumption, while ships use 15% and ground systems use 8% of the total. Over the long range, therefore, DoD has an opportunity to influence its future energy requirements by selecting and developing new systems which are signficantly more energy efficient than current systems.

The Office of the Secretary of Defense (OSD) policies and directives which govern the management process for major system acquisitions call for increased emphasis on energy efficiency. In most cases, the corresponding Military Department directives have been modified to reflect an increased management concern for the energy efficiency of weapon systems. However, the guidance provided by these directives is very general and sometimes inconsistent. As a result, energy conservation and efficiency have relatively little impact on new system selection, design, and development.

Even though an adequate framework to handle energy issues exists in the form of Life Cycle Cost (LCC) and Integrated Logistics Support (ILS) analyses, several difficulties now impede the substantive treatment of energy issues during the acquisition of major systems:

1. Energy-related information developed for OSD program review is scattered throughout various cost, ILS, and other program documents. It is often difficult to identify and evaluate energy issues in a timely manner.

2. There is no explicit requirement to identify and discuss alternative system hardware designs or support concepts in terms of the system's energy consumption. A specific requirement that such alternatives be reported on at appropriate program milestones would encourage more innovative energy option exploration, and would allow more management visibility into system choices.

3. The Military Department and OSD energy staffs do not actively participate in the Defense System Acquisition Review Council (DSARC) or Planning, Programming, and Budgeting System (PPBS) deliberations concerning major weapon systems and forces. Their concentration to date has been on installation and facility energy requirements, and on energy supply issues.

4. System LCC estimates have been using petroleum price forecasts which have proven to be seriously in error on the low side for the last 7 to 10 years. For energy intensive systems, those errors can lead not only to improper system design decisions, but also to a failure to recognize important energy trade-offs. The current practice, therefore, tends to mask or distort significant energy conservation issues.

To correct these deficiencies, the Assistant Secretary of Defense (Manpower, Reserve Affairs and Logistics) should issue a memo which:

1. Specifies more clearly the approach for carrying out the DoD policy of minimizing energy use and substituting alternative fuels for oil and natural gas.

2. Establishes an Energy Review Group (ERG) to determine which programs entering acquisition are "energy intensive." Working through the established Manpower and Logistics Analysis group and the Cost Analysis Improvement Group reviews, the ERG will also be responsible for the identification and review of all energy related issues to be treated at DSARC milestones. The ERG could also serve as the focal point to review system energy issues which occur outside of the formal DSARC process, such as during annual program and budget reviews. A suggested ERG membership is:

   Chairman - Director, Energy Policy
   - Representative of OUSD(R&E)
   - Representative from each Service energy office
   - Representative of OASD(MRA&L) Special Assistant for Weapon Support

3. Requires that for all energy intensive programs, a brief "Program Energy Plan Summary" (PEPS) be provided to the ERG before each DSARC review. The PEPS should describe program energy options, requirements, cost and support concepts.

4. Requires that cost sensitivity calculations be included in all LCC estimates of energy intensive systems to show the impact of changes in the estimated growth rate of the price of petroleum based fuels. These same calculations should be used to highlight the sensitivity of all design choices to various price forecasts.

We believe that, if implemented, the recommended actions can enable the DoD to cope more effectively with the growing problems of energy supply and cost in weapon system acquisition.

PREFACE

The rapidly escalating price of oil and growing U.S. dependence on uncertain overseas oil supplies have made Defense energy a major budgetary, operational and policy issue. The principle focus of management attention to date has been on solving the immediate budget and supply problems. Cutting waste, reducing operations and training activities to a minimum, and substituting more readily available fuels whenever possible have received intense attention. Actions are also underway to assure that adequate supplies exist and to develop effective procedures to assure delivery of the necessary petroleum products to DoD in time of emergency. Over the longer range, however, it has been recognized that the DoD has an opportunity to have an even larger impact on its future fuel requirements by selecting and developing new systems which are significantly more energy efficient than current systems. How the acquisition process can best be used to encourage the development of long-range solutions to the DoD energy problem is the subject of this study.

While the acquisition of all DoD systems, equipment, and materials influences the consumption of energy within DoD, this study is limited to an analysis of the acquisition of major systems and to the energy consumed by operation of these systems. Energy expended by contractors in producing these systems is not considered. The concentration on major systems is purposeful in that other efforts are underway to develop procedures for the acquisition of energy efficient equipment, such as appliances. Perhaps the most important reason to focus on major systems, however, is that the bulk of total energy consumed by DoD, and especially petroleum based fuels, is in the operation of the major systems--the aircraft, ships, and military vehicles that equip our military forces. Fully 89% of all petroleum based fuel used by the DoD is consumed by these major systems. Therefore, the greatest challenge and the largest opportunity for saving fuel is within the major military systems. It follows then that the current selection and development of future systems will determine to a large extent how well the DoD will be able to cope with future energy issues.

The research undertaken in this study of conservation in the acquisition process interprets the word "conservation" in its broadest meaning. Clearly the interest in future systems goes beyond the idea of conservation by cutting down the operational use of a system, and hence its energy consumption. A broader view of conservation involves the objective of being able to accomplish a given military mission while consuming less energy. It is this concept of conservation--that is, increasing energy efficiency, rather than cutting back on operations or capability--which has been used in this study. The language of the implementing documents for Federal agency conservation efforts seems to have intended this broader view; e.g., the April 29, 1977 DoD insert into the DAR states "... energy conservation and efficiency criteria shall be considered ..." in the procurement process; and the Office of Federal Procurement Policy (OFPP), Policy Letter No. 76-1 of August 6, 1976 requested all Federal agencies to "insure that the principles of energy conservation and efficiency are applied in the procurement of property and services...."

As a final comment on the scope of the study, it has been observed that there are two basic management approaches to encouraging improvements in energy efficiency of new systems and equipment. One is the *a priori* specification of energy performance standards for new systems (for example, automobile minimum miles per gallon requirements, or refrigerator maximum power consumption specifications). The other is the requirement that energy conservation be given special emphasis in the cost vs. effectiveness evaluations normally conducted to select the most effective system possible, given the resources available. The former approach has been applied with some success to simple, predictable state-of-the-art equipment, such as appliances, consumer products, and automobiles. In the case of a weapon system, however, whose life cycle from original concept to full deployment can span several decades, and which typically uses technology at the leading edge of scientific capability, the pre-defined standards concept has significantly less application. In the final analysis, all fuel conservation options must be compared to other performance and effectiveness gains that can be bought for the same resources; and they must compete for those resources in the trade-offs which are used in the logical selection of the "best" system design.

For these reasons, the study approach taken is to identify management actions which can be used to encourage, highlight, and clarify the treatment of energy within the exis ing trade-off procedures used throughout the evolution of major weapon systems. Targets and goals are considered for purposes of tracking and verifying energy performance parameters after they have been defined by the usual cost-effectiveness design trade-off procedures.

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I. BACKGROUND

THE NATIONAL PERSPECTIVE

The old adage that an Army marches on its stomach has a modern equivalent: an Army moves on its fuel tank. The Organization of Petroleum Exporting Countries (OPEC) embargo of 1973 forcefully demonstrated U.S. dependence, including DoD, upon oil and its uncertain sources of supply.

The relative cheapness of foreign crude oil through the 1960s had much to do with the rapid increase in the consumption of energy and the growing dependence on imported oil. The United States became a net importer of petroleum in the 1950s, albeit on a very small scale. Early in the 1970s, domestic production of crude peaked; and as a result, imported crude and product satisfied a growing portion of consumer demand. A substantial segment of these imports came from OPEC members.

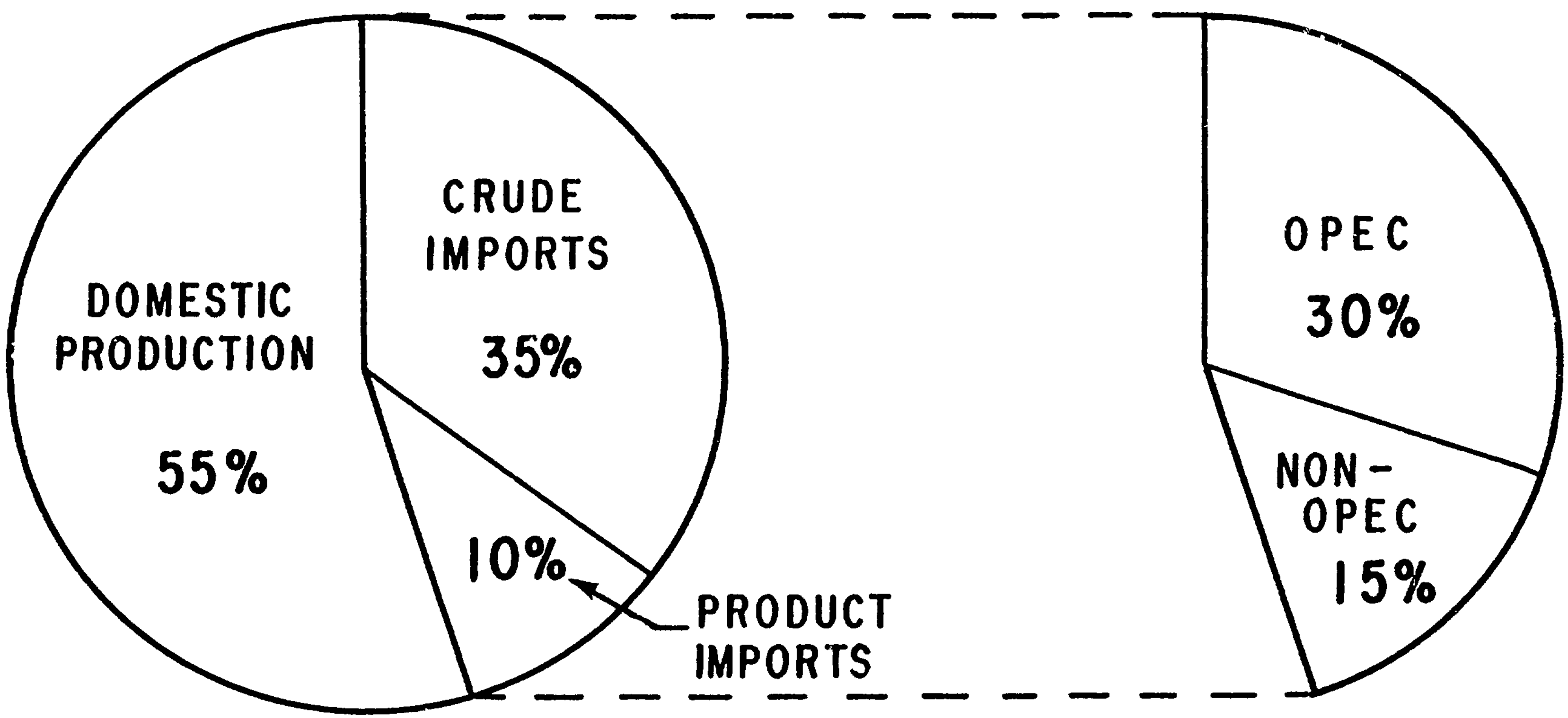
Figure I-1 shows the source of petroleum supplies for the United States for 1979. The average daily consumption of petroleum products in 1979 was 18.6 million barrels. Of this, 45% or 8.4 million barrels per day were imported. Two-thirds of the imports came from OPEC members, and the remaining 2.8 million barrels per day came from non-OPEC sources such as Canada and Mexico.

While domestic production was declining, the world price of crude was increasing. The average price for a barrel of crude was $3.89 in 1973, $7.19 in 1974, and $21.67 in 1979. Without considering the effect of inflation, the real price of crude rose at an annual rate of 28% from 1973 to 1979.

During 1979, the United States paid about $165 million per day to import crude and petroleum products. During the second half of 1979, the price of

FIGURE I-1

SOURCE OF U.S. PETROLEUM SUPPLY - 1979



TOTAL U.S. PETROLEUM SUPPLY
18.6 MILLION BARRELS/DAY

SOURCE OF IMPORTS
8.4 MILLION BARRELS/DAY

SOURCE: DEPARTMENT OF ENERGY, "MONTHLY ENERGY REVIEW", JUNE 1980 crude doubled, going from $14.50 to $29.00 per barrel by December 1979. By August 1980, petroleum imports were running slightly under 6 million barrels per day for a daily import bill of about $190 million.

ENERGY CONSUMPTION BY DoD

The Department of Defense became dependent on oil with the rest of the economy. The introduction of the tank and the airplane in World War I revolutionized the tactics of modern warfare. The advent of the mechanized Army of World War II with its tanks, trucks, and aircraft immensely enhanced the mobility of military forces. The cost of this mobility was paid in part by significant requirements for petroleum products in the logistics chain. The advent of jet aircraft at the end of the World War II accelerated this trend.

In 1979, the DoD consumed about 475,000 barrels per day of petroleum products, or 2.5% of total United States consumption. (DoD uses additional quantities of coal, natural gas, and electricity which are not considered here.)

Table I-1 shows a breakdown of petroleum consumption by product. About 17% of the total is fuel oil consumed primarily to provide utilities and other services for the bases. The remaining 83% is used for mobility consumption, which includes all fuel directly applied to training and operational readiness. Jet fuel accounts for the largest percentage, 65%, of petroleum consumption. The other major products are fuel oil and diesel, accounting for 17% and 14% of consumption respectively.

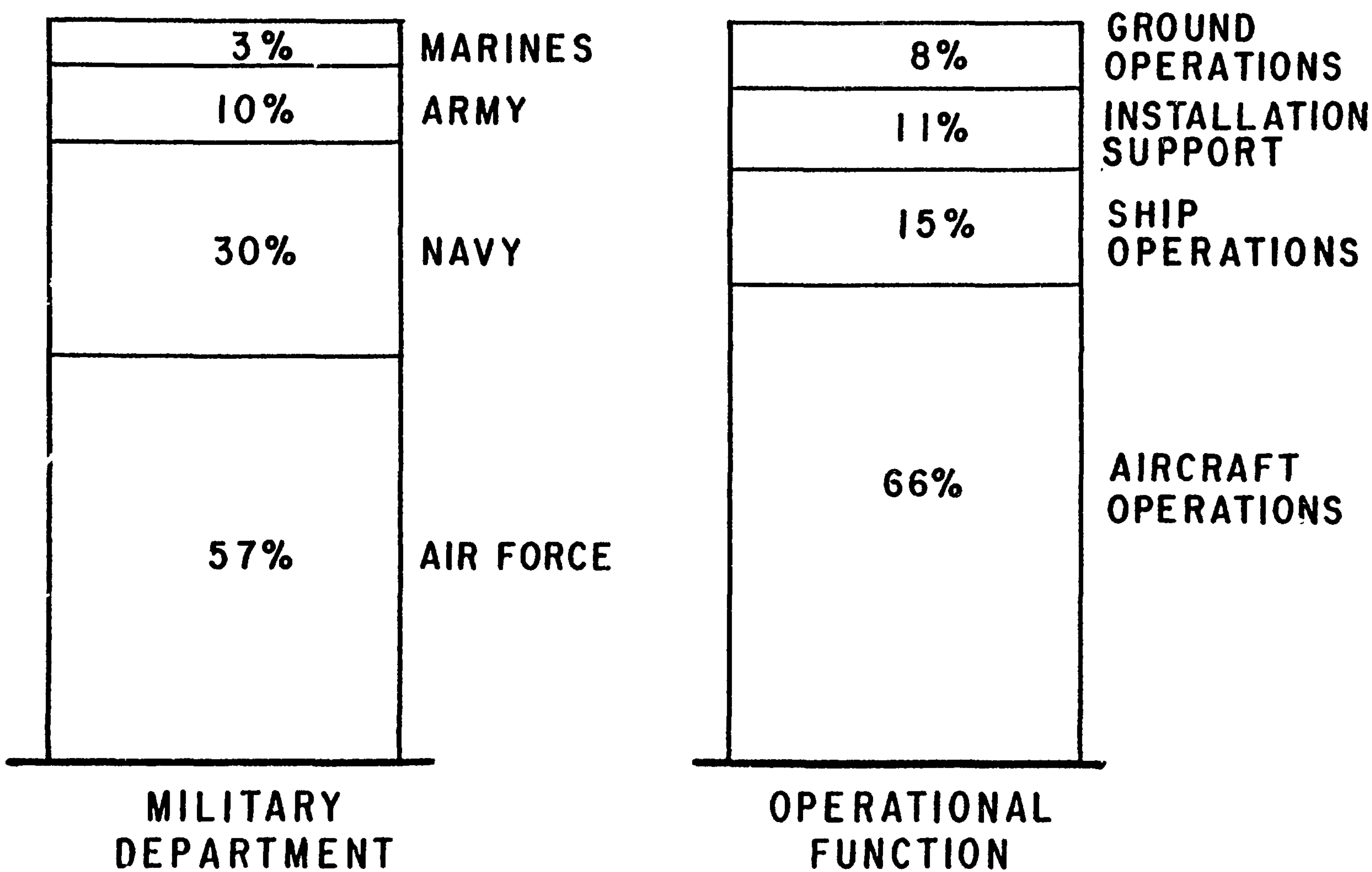
Figure I-2 breaks out petroleum consumption by Military Department and by type of system. Aircraft operations are the largest system consumers of petroleum in the Department of Defense, accounting for 57% of departmental consumption and 66% of functional consumption. Ships consume 15%, or less than one-fourth of aircraft usage, and ground vehicles use 8%, or less than one-eighth of aircraft usage.

FIGURE I-2

PETROLEUM CONSUMPTION BY DEPARTMENT AND FUNCTION

DEPARTMENT OF DEFENSE-FY 1979

(PERCENT)



SOURCE: DEPARTMENT OF DEFENSE ENERGY MANAGEMENT PLAN, JULY 1980

TABLE I-1. DoD PETROLEUM CONSUMPTION BY PRODUCT (FY 1979)

PRODUCT	CONSUMPTION (Barrels per Day)	CONSUMPTION (As a % of Total)
Fuel Oil	79,000	16.6
Auto Gasoline	15,200	3.2
Diesel & Petroleum Distillate	67,300	14.2
Aviation Gasoline	2,100	0.4
Jet Fuel	306,700	64.6
Navy Special	4,500	1.0
TOTAL	474,800	100.0

Source: Department of Defense Energy Management Plan, July 1980.

Table I-2 shows the distribution of petroleum consumption for mobility operations by product and by Military Department. Each Military Department dominates the demand for a specific type of petroleum product. The Air Force uses 76% of the jet fuel consumed; the Navy uses 84% of the distillate fuel; and the Army consumes 50% of the total motor gasoline used.

THE COST OF ENERGY

Figure I-3 summarizes average crude oil prices during the past decade. After a long period of stable prices, foreign petroleum prices quadrupled in 1974; but because domestic crude prices were controlled, the average domestic price paid by refiners did not increase to the level of world prices. The rate of price increase slowed for a couple of years from 1976 to 1978 and then doubled again during 1979-80.

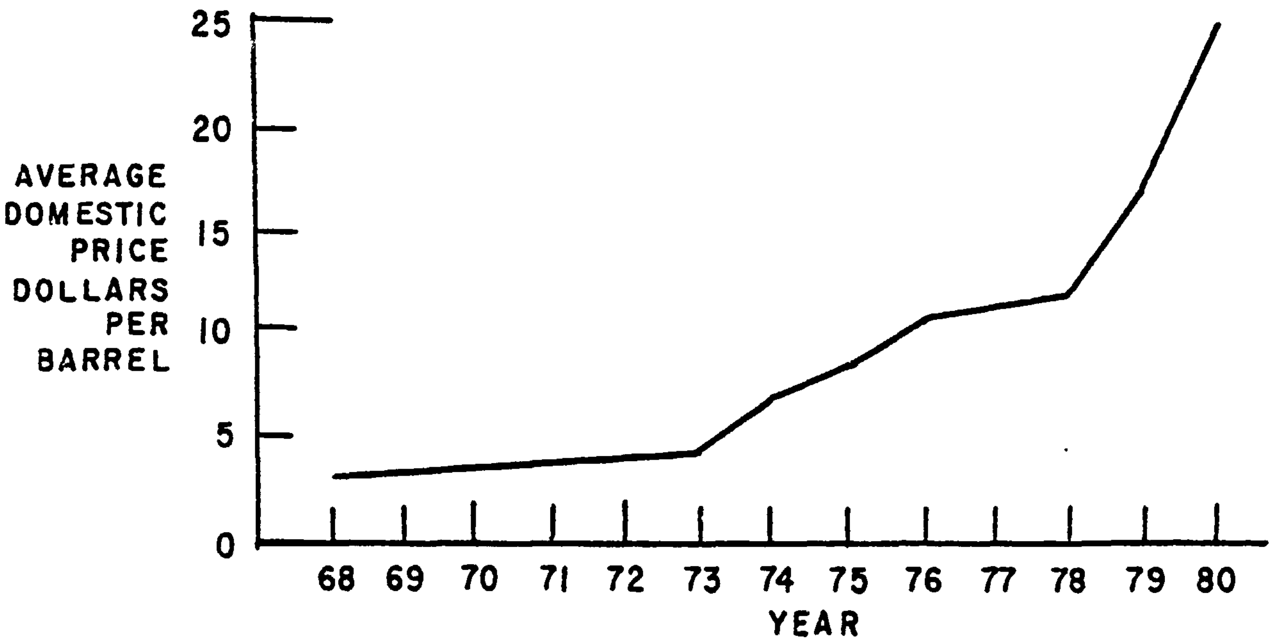
TABLE I-2. PETROLEUM CONSUMPTION FOR MOBILITY OPERATIONS BY PRODUCT AND DEPARTMENT
FY 1977
(%)

	Jet Fuel	Aviation Gasoline	Motor Gasoline	Diesel & Distillate
AIR FORCE	76	39	23	4
ARMY	2	6	50	9
NAVY	22	55	19	84
OTHER DoD	0	0	9	3
TOTAL	100	100	100	100

Source: Military Department Energy Offices

FIGURE I-3

AVERAGE DOMESTIC PRICE OF CRUDE OIL (CURRENT DOLLARS)



SOURCE: AMERICAN PETROLEUM INSTITUTE, "BASIC PETROLEUM DATA BOOK;" DOE, "MONTHLY ENERGY REVIEW"

Figure I-4 graphs DoD annual energy consumption and cost for the fiscal years 1975-80. Even though DoD petroleum consumption remained relatively constant during these six years, the cost of that consumption continued to rise at a rapid rate. The largest cost increase came in the last year when the cost of energy rose from $5 billion in FY 1979 to about $9 billion in FY 1980.

SUMMARY

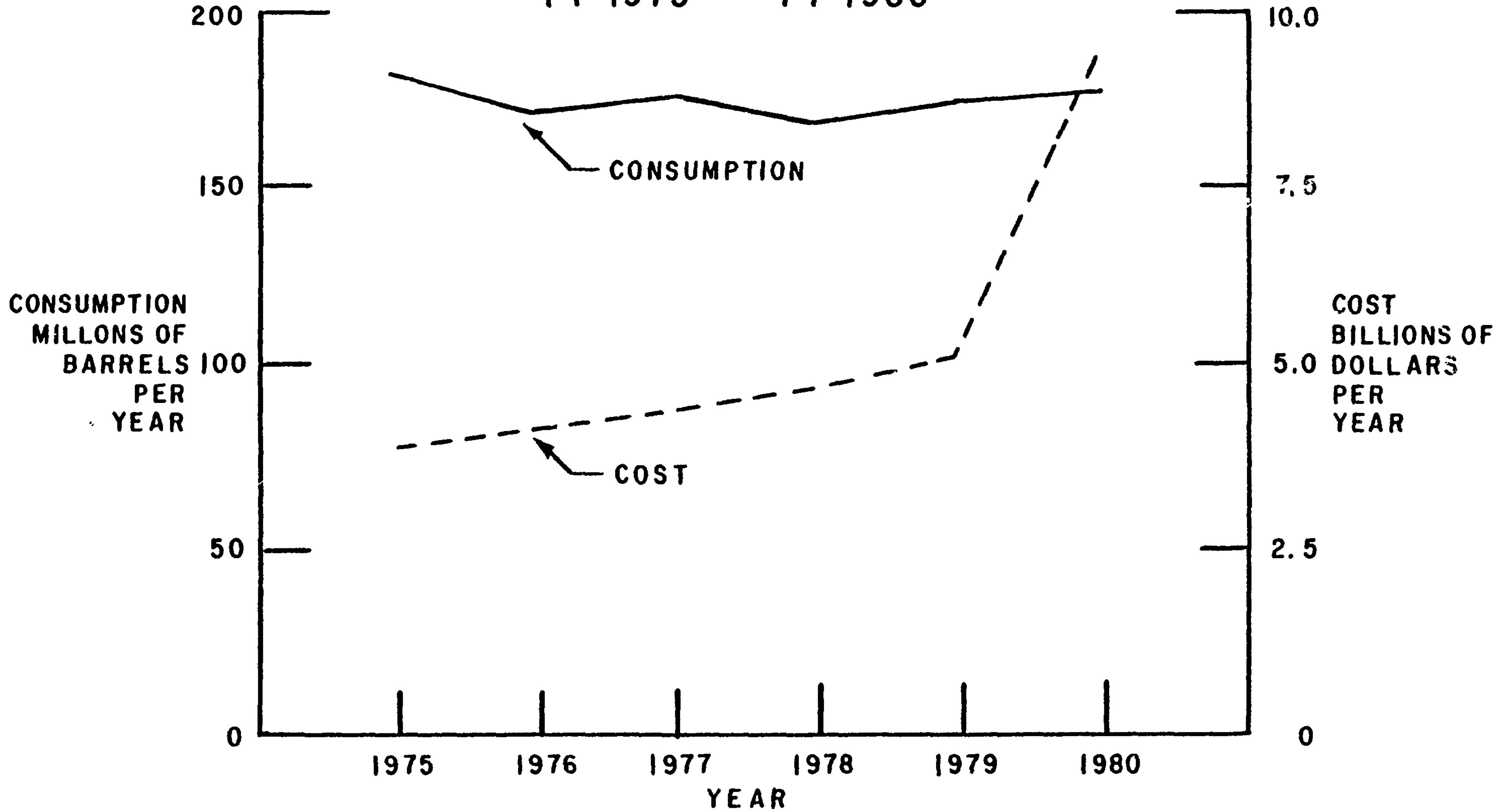
Consumption of petroleum within DoD is predominantly for mobility fuels used by major weapon systems. The single most significant user of petroleum is the jet aircraft; ships are the second largest user but use only one-fourth as much as jet aircraft. Ground vehicles acccunt for only about 8% of petroleum consumption.

Further, the rising cost of crude oil has turned petroleum into a major budget and resource issue. Improving the energy efficiency of future weapon systems, therefore, is of great importance. The following sections discuss how energy efficiency can be more effectively treated during the weapon system acquisition process.

FIGURE I-4

TOTAL ENERGY CONSUMPTION[1/] AND COST FOR THE DEPARTMENT OF DEFENSE

FY 1975 - FY 1980



1/ INCLUDES ELECTRICITY, NATURAL GAS, PETROLEUM AND COAL. PETROLEUM IS 68% OF TOTAL CONSUMPTION.

SOURCE: DEPARTMENT OF DEFENSE ENERGY MANAGEMENT PLAN, JULY 1980

II. ENERGY CONSIDERATIONS IN THE ACQUISITION PROCESS

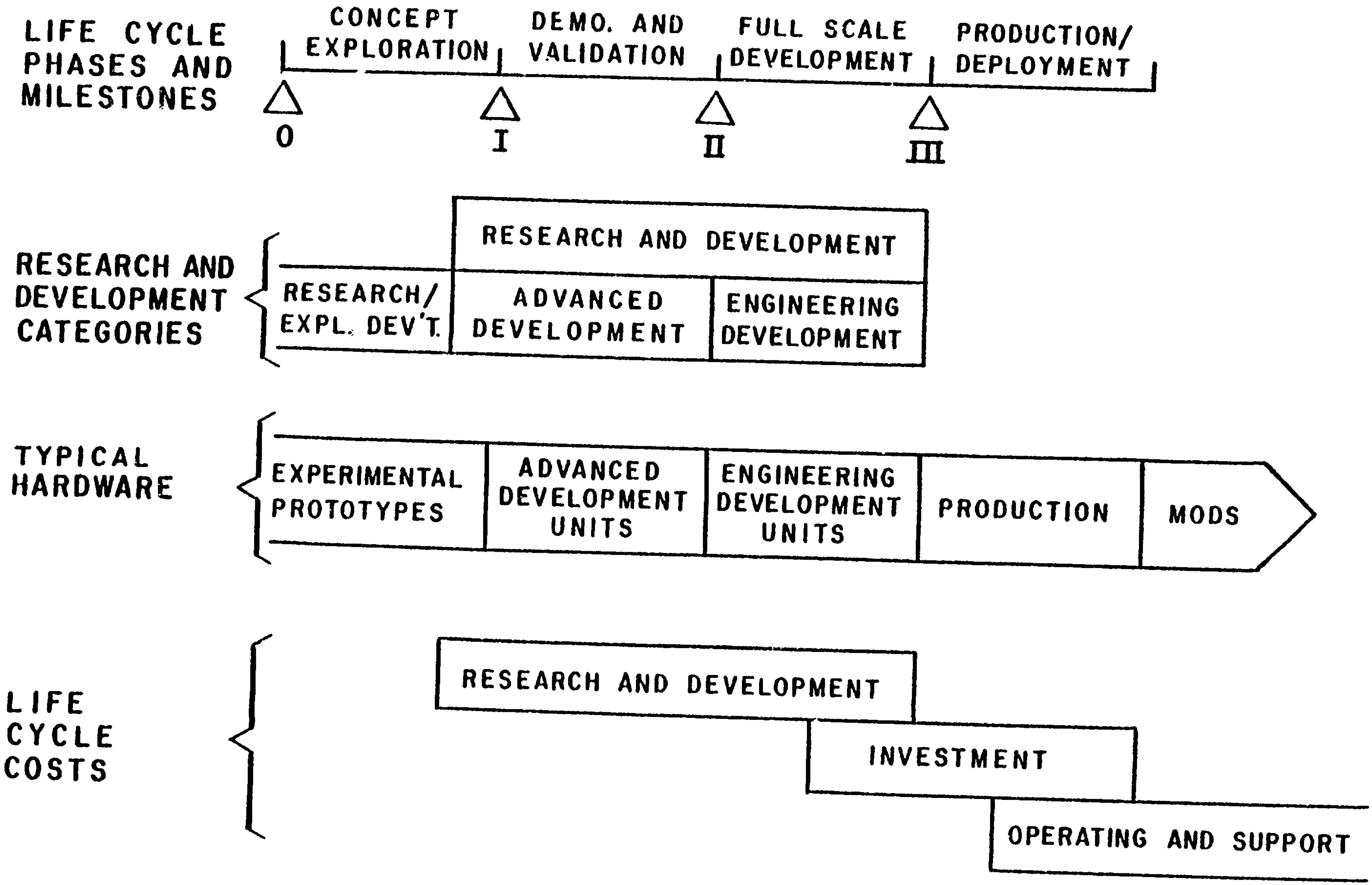
THE PROCESS

Before discussing how energy issues can be more appropriately treated in acquisition management, a brief description of the management process is in order. The DoD management process for major system acquisition is keyed to the various phases through which a major program passes during its evolution from original concept to production and deployment. For management purposes, four phases are defined, each phase beginning and ending at a milestone. At each milestone, a formal program review takes place, key approvals are given and decisions made. These decisions can involve technical, funding, and/or contracting issues, appropriate to the milestone and the specific program details. (See Figure II-1.) Milestone decisions and activities are summarized below:

Milestone	Decisions
0	Approval of Mission Element Needs Statement (MENS) Authorization to proceed into Phase 0 - concept exploration
I	Selection of alternatives to be considered Authorization to proceed into Phase I - demonstration and validation Objectives: validate alternatives, provide basis for decision at Milestone II
II	Selection of alternatives for development Authorization to proceed into Phase II - full scale development Intent to deploy the system Objectives: conduct operational T&E, prepare to produce, demonstrate requirement satisfaction
III	Authorization for Phase III - production and deployment Production and force levels

FIGURE II-I

SYSTEM LIFE CYCLES AND THE ACQUISITION PROCESS



The Defense Systems Acquisition Review Council(DSARC) is an advisory body to the Secretary of Defense which conducts the necessary program review and follow-up activities, and recommends appropriate actions to the Secretary of Defense. The DSARC will normally meet at Milestones I, II, and III and when any technical or cost threshold is breached or threatened. The DSARC is chaired by the USD(R&E), who is the designated DoD Acquisition Executive. Other members include USD(Policy), ASD(Comptroller), ASD(MRA&L), ASD(PA&E), and the Chairman(JCS).

Several key documents are associated with the DSARC process. These documents include basic program information, an outline of the issues and the required decisions to be resolved at the DSARC meeting. They also record previous system estimates, goals and targets, and prior decisions made at milestone reviews. These documents include:

Mission Element Needs Statement(MENS)

- Defines a mission area deficiency, its relative priority, and the desired date of eliminating the deficiency. It is the basis for the Milestone 0 decision.

Decision Coordinating Paper(DCP)

- A key document supporting Milestone I, II, and III reviews. It summarizes program alternatives, issues, and decisions needed. It contains program goals, resources, and life cycle cost estimates.

Integrated Program Summary(IPS)

- This document summarizes the acquisition plan for the system's life cycle, including support planning.

The development of logistics support requirements and the analysis of support alternatives is conducted throughout the weapon system life cycle. By DoD policy, this activity is conducted within an Integrated Logistics Support (ILS) framework. The information and data developed by the Logistics Support

Analysis(LSA) provides a significant input to the descriptive program material used during DSARC review, including plans for maintenance, supply support, training and training devices, energy requirements, facilities, etc. The LSA also provides an important input to the system cost analyses that are performed as part of the continuing cost-effectiveness trade-off activity. Appendix B contains further information on the treatment of energy in LCC analysis and in the ILS data.

The DSARC members draw on advisors for assistance in dealing with various specialized issues as required. Of particular interest to the review of energy issues is the DSARC advisory group for cost matters, the Cost Analysis Improvement Group(CAIG). Its functions can be summarized as follows:

- provide a review of independent cost estimates of the DoD component DSARC cost presentation
- establish criteria, standards and procedures for costs
- identify where technical improvements in estimation are needed
- develop methods to treat cost uncertainty/risk
- help determine relevant costs for DCP/DSARC consideration
- guide the collection, storage and exchange of cost data
- assess/recommend cost objectives in DCP

Program cost analyses, including system Life Cycle Cost(LCC) estimates, are required for each DSARC review. The CAIG has issued Weapon Systems Operating and Support Guidelines to help standardize the operating and support cost elements used in LCC estimates. Within those standardized cost elements are categories which reflect the peacetime fuel costs, war reserve materiel requirements, and all energy related equipment and support costs.

Appendix A contains a more detailed outline and description of the acquisition management process and key policies promulgated by both OSD and the

Military Departments with respect to energy considerations during the acquisition process.

WHERE DOES ENERGY FIT IN NOW?

Within the formalized major system acquisition process, considerations of energy are required as follows:

- The cost of fuel (specifically POL) is an element of operating costs as defined in the CAIG Operating and Support Cost Development Guide. Life Cycle Cost estimates are required for review prior to each DSARC, and the results are documented in DCP Annex C.

- While there is no separately identified ILS energy element, the Integrated Logistics Support(ILS) information should contain definition of the system fuel and energy requirements, including its facility utility needs, and the associated support equipment and personnel. The training concept to be used (e.g., simulators vs. vehicle operation) is also implied in the ILS and various other program data. However, there is no standardized format for energy related information, and there is no integrated section on energy.

- Several policy directives contain general statements which require energy to be considered during the acquisition process. For example, DoDI 5000.2 "Major Systems Acquisition Process" states that--"Energy requirements shall be considered in system selection and design. Major considerations shall be minimal energy usage and the substitution of other energy sources for petroleum and natural gas." This directive also specifies that the IPS should contain a section which summarizes "... the environmental and energy impacts of developing, producing, and operating the DCP systems alternatives."

It can be said, therefore, that within the existing acquisition policies there is a stated requirement to be concerned with energy efficiency, and that energy is to be included in basic program cost and logistics support data.

However, the following deficiencies tend to mask or limit the identification and full treatment of energy alternatives and issues.

1. The Framework for Treating Energy

While appropriate OSD and Military Department directives have been modified to reflect an increased management concern for the energy efficiency of weapon systems during the acquisition process, the guidance provided by these changes is very general and sometimes conflicting concerning the specific approach and methods to be used.

Is energy to be treated as a separate and equal decision parameter along with cost, schedule, and effectiveness in weapon system design? Or is it only one of many parameters which can have an impact on cost and effecttiveness, and therefore is to be considered within the existing trade-off process? No clear-cut statement (or general understanding) now exists which defines the procedures to treat energy efficiency in system acquisition decisions. If energy is to be treated as a unique and additional decision element, new basic methodologies would be required beyond the usual cost-effectiveness trade-off approach. If energy is to be considered within the existing cost-effectiveness decision framework, a need exists simply to make sure that all aspects of energy are adequately reflected in the cost-effectiveness trade-offs. We believe that, as a practical matter, energy can and should be integrated into the existing cost-effectiveness approach used throughout the acquisition process as well as the Planning, Programming, and Budgeting System (PPBS).

2. Improving Management Focus on Energy Issues

The Military Department and OSD staffs responsible for review of energy utilization now have relatively little impact on major system selection, design or development during the formal DSARC process. This is also true for major system modification programs which have significant energy implications and which may not go through the DSARC process, e.g., the KC135 re-engining program. Several of the reasons for the limited influence of energy in major system decisions are:

(a) Energy related information developed for DSARC review is scattered throughout various cost, ILS, and other program documents. There is no requirement to integrate and summarize energy information for ease of review. It is often difficult to identify and evaluate energy issues in a timely manner.

(b) There is no stated requirement to document and discuss alternative system hardware designs or support concepts in terms of the system's energy consumption. For example, it is not required that a range of plausible system concepts which have different fuel consumption characteristics be considered and reviewed at appropriate milestones. Similarly, it is not necessary to consider a range of training concepts which use different combinations of simulator/operational vehicle operations. The specific requirement that such alternatives be considered and reported at appropriate DSARC milestones would tend to encourage more innovative energy option exploration and would allow more management visibility into these system choices.

(c) The Military Department and OSD energy staffs have not yet developed a practice of actively participating in the DSARC or PPBS procedures concerning major weapon systems and forces. Their concentration to date has been on installation and facility energy requirements and on energy supply issues.

3. <u>The Problem of Fuel Price Forecasting</u>

System LCC estimates have been using point estimates of future petroleum prices which have proven to be seriously in error on the low side for the last 7 to 10 years. For energy intensive systems such as aircraft, these errors can lead to improper system design and support decisions or a failure to recognize that important trade-offs should be explored. Does the more efficient fan jet engine justify its higher cost? Which propulsion system is best among many options with differing levels of fuel efficiency and different costs? Is the cost of the training simulator offset by the projected fuel savings? Is the cost of converting an oil fired utility plant to coal justified by the reduced fuel cost? The answer to these questions depends heavily on the projected life cycle costs, particularly the cost of petroleum based fuels, over the life expectancy of the system, typically 20 years or more.

Since the OPEC embargo on crude shipments in late 1973, the price of petroleum and petroleum products has increased at a more rapid rate than most of the price indices commonly used to measure inflation. From 1973 to 1980, for example, the Consumer Price Index grew at an average annual rate of 9.1%, and the Wholesale Price Index grew at 10.9% per year, while the price of jet fuel increased at a 27% annual rate, or about 17% above inflation.

Table II-1 summarizes the forecasts of 1980 crude oil prices by several influential private and government groups. All of the forecasts were in substantial error and tended to be very optimistic about the future growth in oil prices. Real growth rates between 0-4% per year were typically projected, with most projections being near zero, while actual growth rates averaged about 20% per year since 1974. Similar low growth rate assumptions historically have been built into the "official" price deflators promulgated annually for budgeting purposes by the Office of Management and Budget (OMB) and the OASD (Comptroller) for use in projecting O&M appropriation elements, including fuel.[1] These official estimates are commonly used for projecting weapon system LCC elements.

Recent projections of future crude oil prices by various government and private sector economic experts are shown in Table II-2. These recent forecasts continue to predict low growth rates, averaging 0-3% through the year 2000. Equally important is that the forecasts tend to imply that their predictions are relatively precise; when ranges are given, they are narrow.

While recent forecasts may prove to be significantly better than the previous 10 years of forecasts, there is no clear basis to believe so. The important lesson, we believe, is that projecting petroleum prices has become a very difficult and imprecise art since 1973; great uncertainty is one of the most important characteristics of petroleum prices. LCC estimates, therefore,

[1]Beginning in July 1980 the OASD(C) issued separate price deflators for O&M (excluding fuel) and for fuel only, as part of the FY81-82 budget guidance.

TABLE II-1. FORECASTS OF CRUDE OIL MARKET PRICES

PROJECTOR	YEAR OF STUDY	PROJECTED 1980 PRICE (1980 $/BBL)
MIT Energy Lab[1]	1974	$11.40-$14.70
PIES - DOE[1]	1974	$11.40-$18.00
Houthakker-Harvard[1]	1973-74	$ 6.00-$15.50
Houthakker-Harvard[1]	1973-74	$13.20-$35.00
Rand Corporation[2] "Very Large Airplanes"	1976	$20.00
Rand Corporation[3] "Technological Modifications"	1976	$20.00-$25.75
Oak Ridge National Lab[4]	1977	$21.00
Actual Price of Uncontrolled[5] Crude Oil - April	1980	$32.60-$38.80

[1] Summarized in Energy Future: Report of the Energy Project at the Harvard Business School, Edited by Robert Stobaugh and Daniel Yergin, Random House, New York, 1979.

[2] "An Evaluation of Very Large Airplanes and Alternative Fuels," W. T. Mikolowsky, L. W. Noggle, R-1889-AF, Rand Corp., Santa Monica, CA, December 1976.

[3] "The Potential Role of Technological Modifications and Alternative Fuels in Alleviating Air Force Energy Problems," J. R. Gibman, W. L. Stanley, J. P. Weyant and W. T. Mikolowsky, R-1829-PR, Rand Corp., Santa Monica, CA, December 1976.

[4] "Energy in America's Future, The Choices Before Us, a Study Prepared for the RFF National Energy Strategies Project," S. H. Schurr, J. Darmstradter, W. Ramsey, H. Perry, M. Russell, The John Hopkins University Press, Baltimore, MD, 1979.

[5] "Federal Register," Vol. 45, No. 132, 8 July 1980, p. 45943.

TABLE II-2. CRUDE OIL PRICE FORECASTS
(Annual Growth Rates in Percent)

	DOE-EIA (April 1980) (Range)	DOE-EIA (April 1980) (Med. Case)	Data Resources (Winter 1980)	Wharton (April 1980)
1980-1985	-1.5 to 5.1%	1.6%	3.0%	4.1%
1985-1990	0 to 2.7%	2.6%	3.0%	1.8%
1990-1995	0 to 4.8%	2.1%	3.1%	-
1995-2000	0 to 1.5%	1.2%	3.0%	-

Source: Federal Register, 23 June 1980, p. 42193.

should be tested for the effect of changes in fuel price forecasts; and when they are found to effect important system decisions, this fact should be clearly identified and highlighted. Such fuel price sensitivity calculations are not only good analytic procedures, but are required by DoD policy.[2] The current practice of using one forecast, usually the "official" projection, can tend to mask or distort significant system energy conservation issues.

POTENTIAL IMPROVEMENTS

In view of the above, the following recommendations are made:

1. OSD should specify more clearly the approach to be used in carrying out the DoD policy of minimizing energy use and substituting alternative fuels for oil and natural gas.

2. A brief "Program Energy Plan Summary" (PEPS) document, describing program energy requirements, costs, and support concepts should be provided to OSD preceding each system DSARC review.

[2] For example, DoDI 7041.3 "Economic Analysis and Program Evaluation for Program Management" 18 Oct. 1972 calls for "a test of the sensitivity of the results of any factor, including possible side effects, which may significantly impact on the problem under study." See Appendix C.

3. For energy intensive systems, alternative system designs and system support concepts which have an energy impact (e.g., propulsion systems and training simulators) should be considered at appropriate milestone reviews. Cost-effectiveness results or other decision criteria which lead to the preferred system design option should be briefed. These energy-related design trade-offs should also be documented in the PEPS.

4. Cost sensitivity calculations should be provided with all energy intensive system LCC estimates to show the impact of changes in the price of petroleum based fuels. These same sensitivity calculations should be used to highlight all design choices which could be affected by possible changes in the price of fuel.

The next section discusses what energy cost and support issues should be reviewed and where and when those reviews best fit into the system acquisition cycle. Finally, a brief discussion of one means of implementing the recommended changes is provided.

III. PUTTING MORE EMPHASIS ON ENERGY

ENTERING THE PROCESS

The basic objective of emphasizing energy concerns during the acquisition process is to assure that system decisions properly reflect future energy constraints and costs. How this might be accomplished is the subject of this section. The specific system decisions that might be affected by considerations of energy can be catergorized as follows:

Decision	When Made
1. Selection of system concept; e.g. - aircraft vs. other vehicle concept - fixed wing vs. rotary wing - manned vs. unmanned ⋮	Phase 0
2. Hardware/engineering design; e.g. - propulsion concept - size, - weight ⋮	Phases 0, I, II
3. Training concept selection; e.g. - use of simulators ⋮	Phases I, II
4. Force size, deployment decisions - integration into forces - mission assignment - replacement/modernization rate ⋮	Phases II, III

During the normal course of a system's evolution, therefore, a number of basic energy issues should be addressed to determine the potential impact of energy on the system decisions listed above. A checklist of typical energy questions which should be answered at appropriate milestones for energy intensive systems includes the following:

- Are there important differences in energy requirements among alternative system concepts/designs?

- Are all energy support-tail impacts, including war reserves, identified?
- Have training concepts considered energy conservation opportunities?
- Have energy requirements been verified?
- Has POL been properly priced and its uncertainty considered?
- Is the new system compatible with DoD energy goals and objectives?

Table III-1 illustrates how typical time-phased energy issues and questions can be addressed during system acquisition; also listed are typical system decisions that could be affected.

DOCUMENTS AND REVIEW MECHANISMS

The documents which will contain the necessary program and energy-related information at each acquisition milestone are summarized below. Also shown are the two existing OSD reviews (by the CAIG and M&LA group) which can serve as the principal vehicles for review of energy cost and support issues.

	Possible Points of Entry
Phase 0	
- For comment MENS	- Milestone 0 decision document, begins Phase 0
Phase I, II III	
- For comment DCP	- Developed and staffed 3 months prior to DSARC
- IPS, LCC and ILS sections	- Usually acccompanies DCP
- OSD CAIG review of system costs	- 15 days prior to each DSARC
- OSD Manpower and Logistics Analyses (M&LA) review	- 15 days prior to each DSARC
- Program Energy Plan Summary (PEPS)*	- Accompanies DCP for energy intensive programs
All Phases	
- PPBS	
POM, BUDGET, FYDP	- Continuous
- PEPS*	- Annual update

*Recommended new requirement.

TABLE III-1. ENERGY-RELATED SYSTEM CHOICES AND ISSUES

PHASE	CHOICES	ISSUES
0	- System approach e.g. propulsion concept - Support system concept - Training concept - OT&E approach	- Are there important differences in energy requirement's among alternative system concepts/designs? Have alternatives been considered? - Has POL been properly priced and its uncertainty considered? - Have training concepts considered energy conservation opportunities? - Does the new system improve energy efficiency of the mission area? - Is the new system compatible with DoD energy goals and objectives? - Will OT&E validate energy requirements?
I	- System design - Support system structure - Training concept - OT&E plan	- Are there important differences in energy requirement's among alternative system designs? - Has POL been properly priced and its uncertainty considered? - Are full POL support-tail impacts identified? - Have training concepts considered energy conservation opportunities?
II	- Support and training details - Energy targets/goals	- Has POL been properly priced and its uncertainty considered? - Are full energy requirements identified? - Have energy requirements been validated?
III	- Production level - Support operations	- Has POL been properly priced and its uncertainty considered? - Have energy requirements been validated? - Are system energy requirements programmed?

The Program Energy Plan Summary (PEPS), mentioned in the previous section, is envisioned as a brief compilation of relevant program energy information. The basic information called for is now contained in or required for the development of the IPS, various ILS documents, and LCC estimates. It is felt that in most cases a 20-30 page document would be sufficient. Its content should include:

- Total system energy requirements
- System energy alternatives
- Energy support requirements
- Training concept
- War reserve POL requirements
- LCC estimates; sensitivity analysis

It is recommended that the cost sensitivity calculations performed at each milestone contain at least the following LCC cases:

(a) "base case" using the official OASD(C)-prescribed fuel escalation rates (usually 0% to 2% per year real growth)[1]

(b) "nominal growth case", assuming that the real growth rate of POL is 5% to 10% per year

(c) "decision cross-over case" when significant energy alternatives have been evaluated. In this case the real growth rate of fuel is found which makes the alternatives equal in life cycle cost.

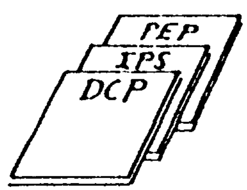
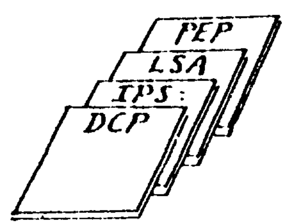
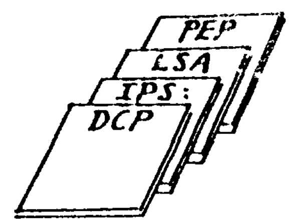
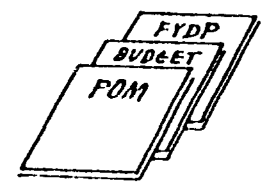
Table III-2 summarizes the recommended system energy management process during the life cycle of a typical system acquisition.

IMPLEMENTATION

In order to implement the previous recommendations, several steps will have to be taken to introduce the necessary changes into the acquisition process. Assuming that the new procedures are to be formalized and the oversight

[1]For example, OASD(C) issued FY1982 Budget Estimate Guidance of July, 1980 specified fuel price escalation factors which imply 0% real price growth.

TABLE III-2. ENERGY MANAGEMENT DURING ACQUISITION

0 — I	I — II	II — III	III →
CONCEPT EXPLORATION	DEMONSTRATION AND VALIDATION	FULL-SCALE DEVELOPMENT	PRODUCTION AND DEPLOYMENT
• IDENTIFY AND EXPLORE ENERGY ALTERNATIVES	• ENERGY SUPPORT REQUIREMENTS OF SYSTEM	• DETAILED ENERGY SUPPORT REQUIREMENTS	• FOLLOW-UP REVIEWS DURING PPBS
• IDENTIFY ENERGY SUPPORT REQUIREMENTS	• ALTERNATIVE TRAINING/ OPERATIONS CONCEPTS	• DEFINE TRAINING APPROACH	• ENERGY USE VS. GOALS
• DETERMINE SYSTEM SENSITIVITY TO ENERGY REQUIREMENTS AND COSTS	• FACILITY REQUIREMENTS	• VALIDATE SYSTEM ENERGY REQUIREMENTS	• UPDATE LCC
• LCC ANALYSIS INCLUDING SENSITIVITY	• LCC ANALYSIS INCLUDING SENSITIVITY	• COMPARE ENERGY REQUIREMENTS TO GOALS	
	• ESTABLISH ENERGY LC GOALS/TARGETS	• UPDATE LCC	
			

responsibility within OSD is to be within the energy policy directorate of OASD(MRA&L), the following actions are suggested:

1. A Defense Energy Program Policy Memorandum (DEPPM) is issued to the Military Departments and appropriate ASD cffices which clarifies the implementation of the general energy acquisition policies stated in the 5000 series DoD directives. Specifically, the DEPM would call for:

   (a) the identification of all "energy-intensive" major programs currently in the acquisition process. Energy-intensive programs are those programs which will require significant amounts of energy during their life cycles, and which have an impact on total DoD energy needs. In general, all aircraft and ship programs will be designated energy-intensive. A one time review of all other approved programs in acquisition will be conducted to identify those which are energy-intensive. As new programs enter the acquisition cycle, determinations will be made whether or not they are energy-intensive.

   (b) a review of energy-intensive programs at each milestone, specifically with respect to energy-related alternatives as described in Table III-2. The review would be a part of the OSD Manpower and Logistics Analysis briefing which is scheduled at least 15 days prior to each DSARC milestone.

   (c) the submission to OSD of a PEPS along with the for-comment DCP for those programs designated energy intensive.

   (d) the inclusion of fuel price sensitivity calculations, as summarized in the PEPS, in the CAIG cost briefing and review.

   (e) the establishment of an Energy Review Group (ERG) whose functions would include the identification and designation of all "energy-intensive" programs and the review of these programs at each milestone. The ERG would be responsible for the review of the PEPS, and the review and staffing of DCP's with respect to energy issues. It would also recommend DSARC energy issues, input to the CAIG review via the ASD(MRA&L) representative, and recommend program energy goals and targets as necessary. The ERG could also be used as the focal point to review system energy issues which occur outside of the formal DSARC process, such as during POM/budget reviews. A suggested ERG membership is:

      Chairman - Director Energy Policy
      - Representative of OUSD(R&E)
      - Representative from each Service energy office
      - Representative of OASD(MRA&L) Special Assistant for Weapon Support

2. A memo from the DASD(Energy, Environment & Safety) is transmitted to the chairman of the CAIG, requesting support in increasing attention to energy-related costs, and especially to the problem of fuel price forecasting in LCC estimates. The memo would encourage further study of the fuel price uncertainty issue in order to provide better guidance to the Military Departments in ways of handling this problem; meanwhile it would recommend that the specific sensitivity cases defined above be required for all energy-intensive LCC estimates.

The above implementation approach is based on the fact that all of the recommendations are consistent with existing DoD Directives and OSD policies, and that the establishment of energy data requirements and the review group is simply a clarification of the means by which DoD policy will be carried out. For this reason, implementation should be more straightforward than the case where existing DoD Directives or Instructions would have to be modified.

In summary, we believe that the recommended actions, if implemented, can enable the DoD to cope more effectively with the growing problems of energy supply and cost in weapon system acquisition.

IV. SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

This section provides a listing and summary of the findings, conclusions and recommendations found in previous sections of the report.

FINDINGS

1. Appropriate OSD and military department directives have been modified to reflect an increased management concern for the energy efficiency of weapon systems during the acquisition process.

2. The guidance provided by these directives is very general and sometimes conflicting concerning the approach and methods to be used in treating energy efficiency.

3. Energy conservation and efficiency currently has relatively little impact on major system selection, design or development.

4. There are several existing, well developed acquisition concepts, including life cycle costing (LCC) and logistics support analysis (LSA), which could be used to increase emphasis on system energy efficiency during the acquisition review process.

5. The cost analyses of new energy-intensive systems do not adequately treat the sensitivity of alternative system costs to the large uncertainty in future fuel prices.

6. The Logistics Support Analysis (LSA) process has the following shortcomings with respect to identifying key energy issues during the early phases of system acquisition:

   a. the total energy-related support requirements of new systems are not integrated or summarized in a single document.

   b. the total POL "support tail" is not always defined and analyzed for alternative systems; these impacts can be important cost, manpower, and supportability issues.

7. The dramatic increase in the cost of energy during the last 5 years has made fuel the major part of the direct cost of operating many weapon systems; e.g., fuel represented 22% of the average flying hour cost of USAF aircraft in 1973; in 1980 that percentage has grown to 53%.

8. Estimates of future petroleum prices, including "official" DoD estimates, have proven to be seriously and consistently in error on the low side.

9. The conclusions regarding the cost-effectiveness of many energy investment and technology programs have been biased by inaccurate price projections; i.e., many programs shown to be not cost-effective could, in fact, be cost-effective.

10. A variety of LCC methodologies is used within DoD (and the rest of the government) to evaluate the cost-effectiveness of energy "conservation" investment projects. As a result, all projects cannot be directly compared or ranked on a common basis for resource allocation purposes.

CONCLUSIONS

1. Energy conservation opportunities and issues should be explicitly treated in the DSARC process for energy-intensive new systems. Energy should increasingly affect the selection, timing, and design of new systems, including their operational support and training concepts.

2. The Services should be required to include an integrated summary of energy-related information normally submitted in various documents for DSARC reviews.

3. The energy information should include:

   a. energy consumption rates and total requirements by individual weapon, and for planned force structure of the proposed alternatives compared to the system being replaced.

   b. differences in energy requirements and efficiency among alternative system designs and operational concepts.

   c. impacts of the new system on total energy support requirements (e.g., fuel storage, handling, transporation, manpower).

   d. impact of the new system on petroleum war reserve requirements.

   e. descriptions of alternative training strategies considered re their fuel efficiency.

   f. impact of the new system on Military Department and DoD energy goals.

   g. energy goals or targets, if any, established for the new system.

   h. differences in LCC of alternative system designs having differing energy requirements.

   i. LCC sensitivity to changes in projected fuel prices.

4. In view of the historical difficulty in realistically forecasting fuel prices, and of the consistent tendency to underestimate their growth rate, fuel price sensitivity calculations should be included in all LCC estimates used in energy-intensive program decisions.

5. A standard cost-effectiveness methodology should be selected and used to evaluate <u>all</u> DoD conservation-type programs, including facility modifications (e.g., FAST projects) and major system modification and acquisition programs (e.g., KC-135 reengining). This common basis can be used to rank and prioritize all energy conservation initiatives on an investment, cost-effectiveness basis.

6. An overall review of DoD energy programs should be conducted to assess the impact of recent dramatic increases in petroleum prices. Since some calculations supporting the current strategy were based on erroneous projections, program priorities may have changed and some projects formerly rejected may now be cost-effective.

RECOMMENDATIONS

1. OSD should specify more clearly the approach for carrying out the DoD policy of minimizing energy use and substituting alternative fuels for oil and gas.

2. An OSD Energy Review Group (ERG) should be established to identify, review, and recommend actions on major program energy cost and support issues. The ERG should work through the CAIG and M&LA groups.

3. The Military Departments should be required to submit a Program Energy Plan Summary (PEPS) prior to each DSARC review of energy intensive programs.

4. All energy intensive system LCC estimates should include calculations which show sensitivity to changes to fuel price estimates.

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APPENDIX A

ENERGY CONSIDERATIONS IN THE MAJOR SYSTEMS ACQUISITION PROCESS

THE ACQUISITION PROCESS

The major systems acquisition process provides the formal means by which deficiencies in defense capabilities are recognized and corrected through the development and deployment of new or improved hardware. A great deal of the responsibility and authority related to major systems acquisition remains, as a matter of policy, at the level of the proponent service or defense agency. Nevertheless, the Secretary of Defense has the ultimate responsibility for program approval.

Table A-1 lists the principal Department of Defense Directives which define the acquisition process.

TABLE A-1. KEY DOCUMENTS FOR MAJOR WEAPON SYSTEM ACQUISITION

DODD 5000.1	Defines "major" systems, establishes milestones
DODI 5000.2	Defines the major system acquisition process, the DSARC, MENS, and DCP
DODD 5000.3	Establishes the test and evaluation process the DD(T&E)
DODD 5C00.4	Establishes the independent parameteric cost review process and the CAIG
DODD 5000.30	Establishes the Defense Acquisition Executive
DODD 5000.39	Establishes policies for the acquisition and management of Integrated Logistics Support for systems and equipment

Major decision points occur at the beginning of four sequential program phases: concept exploration, demonstration and validation, full-scale development, and production and deployment. Each decision point is designated by a milestone, at which time Secretary of Defense approval is required before a program may proceed into its next phase. The milestones and their decisions are as follows.

Milestone 0 Decision
Approval of the Mission Element Needs Statement (MENS) and authorization to proceed into Phase 0--Concept Exploration--which includes solicitation, evaluation and competitive exploration of alternative system concepts. Approval to proceed with concept exploration also means that the Secretary of Defense intends to satisfy the need if satisfactory system solutions can be defined.

Milestone I Decision
Selection of alternatives and authorization to proceed into Phase I--Demonstration and Validation.

Milestone II Decision
Selection of alternative(s) and authorization to proceed into Phase II--Full Scale Development--which includes limited production for operational test and evaluation. Approval to proceed with Full Scale Development also means that the Secretary of Defense intends to deploy the system.

Milestone III Decision
Authorization to proceed into Phase III--Production and Deployment.

A milestone 0 decision is triggered by the proponent's submission of a Mission Element Needs Statement (MENS). A format for the MENS is contained in enclosure 2 to DoDI 5000.2. The MENS identifies and defines: (a) a specific deficiency or opportunity within a mission area; (b) the relative priority of the deficiency within the mission area; (c) the Defense Intelligence Agency (DIA) validated threat forecast or other factor causing the deficiency; (d) the date when the system must be fielded to meet the threat; and (e) the general magnitude of acquisition resources that the DoD Component is willing to invest to correct the deficiency. A MENS is required for each acquisition, including system modifications and additional procurement of existing systems, which the DoD proponent anticipates will cost in excess of $100 million in research, development, test and evaluation funds or $500 million in procurement funds.

A Secretary of Defense Decision Memorandum, or SDDM, documents the Secretary of Defense's Milestone 0 decision including approval of goals and thresholds for cost, schedule, performance, and supportability, exceptions to the acquisition process; and other appropriate direction.

Documentation for the program reviews at Milestones I, II, and III is provided by the Decision Coordinating Paper (DCP), the Integrated Program Summary (IPS), and the Milestone Reference File (MRF). Detailed formats for the DCP and IPS, are contained in enclosures to DoDI 5000.2.

The DCP provides the primary documentation for use by the DSARC in arriving at the milestone recommendation. It summarizes the program and the acquisition strategy, the alternatives considered, and the issues to be resolved at the milestone review.

The IPS summarizes the implementation plan of the DoD Component for the complete acquisition cycle with emphasis on the phase the program is entering. The IPS provides a management overview of the entire program. DoDI 5000.2 prescribes a list of topics and a format for the IPS. Item 21 is of particular interest and is specified as follows.

> Energy, Environment, Health and Safety. Summarize the environmental and energy impacts of developing, producing, and operating the DCP systems alternatives.
>
> Specifically, for energy considerations:
>
> (1) At Milestone I. Establish tentative design goals, or range of values, for energy efficiency and substitution at the system level that are responsive to projected needs of the mission area. These goals should be shown in comparison to energy efficiency and substitution capability of similar systems.
>
> (2) At Milestone II. Establish firm energy related goals when appropriate and state trade-offs made between the design, operating concepts, simulators, and any substitution objectives.
>
> (3) At Milestone III. Review energy consumption projections and efficiencies and their sensitivities to system populations.

A MRF provides a central location for existing program documentation referenced in the DCP and IPS. This working file is provided by the DoD Component to the DSARC Executive Secretary at the time a "For-Comment DCP" and IPS are submitted.

The formal OSD milestone program reviews are conducted by the Defense Systems Acquisition Review Council. The DSARC is the Secretary's advisory body for major systems, and as such makes recommendations to the Secretary regarding the disposition of all major programs. The permanent members of the DSARC are:

Defense Acquistion Executive - Chairman, Under Secretary of Defense (Research and Engineering)
Under Secretary of Defense for Policy
Under Secretary of Defense (Research and Engineering)
Assistant Secretary of Defense (Manpower, Reserve Affairs and Logistics)
Assistant Secretary of Defense (Program Analysis and Evaluation)
Assistant Secretary of Defense (Comptroller)
Chairman of the Joint Chiefs of Staff

The DSARC normally convenes at Milestones I, II, and III, but it may convene at any time following milestone 0 should signficant program issues arise which require resolution. The DSARC members are supported by several advisors and advisory groups. They include:

Assistant Secretary of Defense (Communications, Command, Control, and Intelligence)
Deputy Secretary of Defense on NATO Affairs
Deputy Under Secretary of Defense for Research and Engineering (Acquisition Policy)
Appropriate Deputy Under Secretary of Defense for Research and Engineering to deal with program matters
Appropriate Deputy Under Secretary of Defense Policy for operational requirements issues
Director, Defense Intelligence Agency
Director of Defense Test and Evaluation
Chairman of the Cost Analysis Improvement Group
Director, Weapons Support Improvement Group

The planning schedule for each milestone is specified in DoDD 5000.2 as follows:

Event	Schedule in Relation to Date of DSARC Meeting
Milestone Planning Meeting	- 6 months
For Comment DCP and IPS	- 3 months
DCP Comments to DoD Components	- 2 months
Final DCP and Update to IPS	- 15 workdays
OSD Cost Analysis Improvement Group (CAIG) Briefing	- 15 workdays
OSD Test and Evaluation (T&E) Briefing	- 15 workdays
OSD Manpower and Logistics Analysis (M&LA) Briefing	- 15 workdays
DIA Report to DSARC Chair	- 10 workdays
DSARC Chair's Pre-Brief Meeting (OSD Staff Only)	- 5 workdays
CAIG Report	- 3 workdays
T&E Report	- 3 workdays
M&LA Report	- 3 workdays
DSARC Meeting	0
SDDM issued to DoD Component	+ 15 workdays

THE CONSIDERATION OF ENERGY WITHIN THE ACQUISITION PROCESS

As stated previously, the DoD 5000 series of directives for major system acquisition requires that energy be considered in system selection and design. There are three other DoD directives which, while not dealing solely with system acquisition bear on the considerations of energy during various phases of system acquisition. The relevant parts of the three are discussed below.

DoDD 4170.10 Energy Conservation (29 March 1979)

This response to federal energy conservation goals stipulates that DoD conservation efforts will be implemented without adversely affecting mission capabilities or readiness. It assigns OASD(MRA&L) the responsibility to establish conservation program goals for DoD, to develop procedures for monitoring their accomplishment, and to develop an overall plan for conservation in DoD. OUSDR&E is assigned responsibility to establish a program to improve energy efficiency in propulsion systems, both old and new. In addition, that office is charged to establish DoD policy to ensure that energy conservation is considered in the concept formulation, design, selection and production of weapons systems.

DoDD 4140.43 Department of Defense Liquid Hydrocarbon Fuel Policy for Equipment Design, Operation and Logistics Support (5 December 1975)

This directive is concerned primarily with the supply and availability of fuels. It mandates that the military departments achieve greater flexibility in the types of fuels used in military missions such that use can be made of a wider range of military and commercial fuels. This requirement is to be fulfilled by design of new power plants which incorporate the desired fuel flexibility.

DoDI 7041.3 Economic Analysis and Program Evaluation for Resource Management (18 October 1972)

This instruction outlines policy guidance on the use of various methods of economic analysis for proposed programs and the evaluation of continuing programs. One section of this instruction provides guidance on economic analysis which is to be performed when there are "major changes in initial study assumptions." Other sections cover the methodology to be used in calculating discounted life cycle costs, and how to treat inflation.

Within the cost analysis section, methods for performing cost benefit analysis, and incorporating uncertainty are suggested. The use of sensitivity analysis to handle uncertainty in important system parameters is also called for.

The Military Departments have also included energy considerations within their regulations. A review of the most pertinent regulations follows.

U.S. ARMY

At present the Army has issued no formal guidance for energy consideration in the acquisition process. However, draft revisions to two Army Regulations (AR) which would include energy considerations in the acquisition process are currently circulating:

AR 1000-1	Basic Policies for Systems Acquisition (15 May 1978)
AR 71-9	Force Development Materiel Objectives and Requirements (1 April 1975)

The draft change to AR 1000-1 states that energy requirements will be "a primary consideration in the exploration of alternative systems concepts, to include an evaluation of the performance, economic, and readiness impact of using alternative fuels/energy sources."

This change will be incorporated in AR 1000-1 subsequent to the promulgation of DoDD 5000.1 and DoDD 5000.2.

The revised AR 71-9 was not available for review.

U.S. NAVY

Four Navy instructions were found to be germane to the subject:

OPNAVINST 4100.5A	Energy Resource Management (9 May 1978)
NAVMATINST 4100.16A	Energy Management (EM) Plan (12 October 1979)
NAVMATINST 5000.19B	Weapons Systems Acquisition Program Review and Appraisal within the Naval Material Command (21 February 1978)

NAVMATINST 5000.22A Weapon System Selection and Planning (14 July 1977)

OPNAVINST 4100.5A requires that an energy effectiveness review should be incorporated into the system acquisition and planning process. It states that

> "All Navy systems in the program initiation, demonstration and validation, full-scale engineering development, and production and deployment phases will be subject to this review. The objective is to integrate energy consumption data as an element of operating and support cost in the Life Cycle Cost (LCC) and Design to Cost goals. These energy effectiveness reviews will include major systems, components, and subsystems within the acquisition process."

NAVMATINST 4100.16A implements OPNAVINST 4100.5A within the Naval Material Command. Its scope is broad and its guidance is very general with respect to the role of energy in the acquisition process.

A key responsibility for energy in the acquisition process within the Naval Material Command is the Assistant Deputy Chief of Material Acquisition for Acquisition Control. NAVMATINST 5000.19B promulgates the policy and procedures within which this organization operates. With regard to program review presentations before this group, it states that they

> "shall be structured to focus on the program status and projection, existing and anticipated deviations from the program plan, significant problems, and issues of concern. Areas which shall be addressed (as they apply to the nature and developmental phase of the program being reviewed) are:
>
> 1. mission profile/capability
> 2. performance objectives
> 3. reliability/maintainability goals
> 4. energy consumption goals"

NAVMATINST 5000.22A contains no significant guidance with respect to energy consumption. However, this instruction will be revised subsequent to the promulgation of DoDI 5000.2, to help implement the specific energy related guidance contained in DoDI 5000.2.

U.S. AIR FORCE

Several Air Force Regulations (AFR) relate to the role of energy in the acquisition process:

AFR 800-3	Acquisition Management: Engineering for Defense Systems (17 June 1977)
AFR 800-2	Acquisition Management: Acquisition Program Management (14 November 1977)
AFR 800-8	Acquisition Management: Integrated Logistics Support (ILS) Program (7 February 1980)
AFR 800-11	Life Cycle Cost Management Program (22 February 1978)

DAFHQ Operating Instruction 800-2 Acquisition Management: Program Management Direction

AFR 800-3 mandates that the Air Force Systems Command (or other implementing command) will ensure that the concept of energy effectiveness and the requirements of DoD's Liquid Hydrocarbon Fuel Policy (DoDD 4140.43, paragraph IV) be applied to all new engine developments. Energy effectiveness is defined in this regulation as the requirement for "the least critical energy investment, the widest range of energy use capabilities, or the most efficiency in terms of energy used." The regulation further states that "consideration should always be given to the potential impact of the decision (choice) on finite energy resources." This definition was first incorporated in AFR 800-3 in the form of a change on 25 February 1975.

AFR 800-2 implements DoDD 5000.1 and DoDI 5000.2. At present, it does not specifically address energy consumption but it will be revised to include some treatment of energy consumption subsequent to the promulgation of DoDD 5000.1 and DoDI 5000.2.

AFR 800-8 was revised recently (7 February 1980) to require that ILS planning reflect the most energy efficient support approach for a system through trade-off analyses, comparison to developed conservation goals, and performance of system modifications. Energy Management (EM) was explicitly added as an ILS element in this revision even though it was not added as an ILS element in OSD's recently revised corresponding directive (DoDD 5000.39-Integrated Logistics Support Management.)

AFR 800-11 (LCC Management) addresses weapon system energy consumption explicitly only in that Petroleum/Oils/Lubricants (POL) are included as a formal element (301.3) within the generalized cost element structure promulgated with the regulation.

DAFHQ Operating Instruction 800-2 (Draft) provides direction for developing, coordinating, approving, and distributing the Air Force's Program Management Directive (PMD). The PMD is a contract between the Secretary of the Air Force and the Acquisition Program Manager. It plays the same role within the Air Force as the Decision Coordinating Paper (DCP) plays between the Secretary of Defense and the Secretary of the Air Force. The Operating Instruction 800-2 draft states that

> "the effort directed by this PMD must include careful and complete consideration of energy effectiveness in terms of optimum use of energy expended while continuing to meet the operational requirement. Energy effectiveness shall be a major management consideration, along with cost, schedule and performance criteria, in the development, acquisition and support of the effort directed herein."

This is the strongest statement we have found with respect to the role that energy effectiveness should play.

The above documentation indicates that there has been considerable policy emphasis on increasing the role of energy within the acquisition process. However, specific and standardized implementing procedures describing how energy efficiency should be measured, analyzed and included in the decision process has not yet been developed at the OSD or service level.

APPENDIX B

ENERGY IN LIFE CYCLE COSTING AND INTEGRATED LOGISTICS SUPPORT

This Appendix discusses the specifics of where and how energy enters into life cycle cost, including the energy consumed by the system and the energy needed to support the system. Support energy is analyzed within the Integrated Logistics Support (ILS) framework.

ENERGY IN LIFE CYCLE COSTS

A weapon system's Life Cycle Cost (LCC) estimate consists of the total costs associated with the system to acquire, operate, support and retire the system.

A generic set of major LCC categories for military systems is outlined in Table B-1. In practice the cost structure is expanded to include more detailed and system-peculiar cost elements. Table B-2 illustrates a detailed set of typical cost categories recommended by the CAIG for aircraft systems. Similar structures have also been derived for ships, combat vehicles and missiles. Of specific interest in this discussion are those cost elements that are energy-related: Element (301.3) Petroleum, Oil and Lubricants (POL) is the most obvious and significant energy cost. Elements (202.1) Support Equipment, (202.6) Facilities, and (202.7) War Reserve Materiel should reflect support investment costs for special fuel storage, handling and transportation equipment for peacetime operating and war reserve fuel requirements. Item (307.1), Individual Training, can also affect energy use when training operations and fuel are traded off against the use of training simulators. There are often opportunities to trade future energy use with current investment in the (100) Research and Development and (201) Weapon System Investment categories as well.

TABLE B-1. WEAPON SYSTEM LIFE CYCLE COST CATEGORIES

100 RESEARCH AND DEVELOPMENT

200 INVESTMENT

- 201 Weapon System Investment
- 202 Support Investment

300 OPERATING AND SUPPORT

- 301 Deployed Unit Operations
- 302 Below Depot Maintenance
- 303 Installations Support
- 304 Depot Maintenance
- 305 Depot Supply
- 306 Second Destination Transportation
- 307 Personnel Support and Training
- 308 Sustaining Investments

In addition to the costs that are directly associated with a weapon system, there may be collateral costs that are energy-related, and are incurred as a consequence of the decision to acquire and operate a new system. The procurement and operation of new or additional fuel transport vehicles is an example. Such costs would not necessarily show up as part of the weapon system program element or in the system LCC estimate. This is due to budgetary conventions and to the fact that such costs cannot readily be allocated to particular systems. However, when such costs are incurred as a consequence of the acquisition and operation decision, it is appropriate for DSARC purposes to estimate them along with the direct costs, even though such costs may be charged elsewhere in the planning, programming, and budgeting process. In particular, when energy-related collateral costs are very different for alternative system designs, and when they are significant in size, they should be considered during the cost-effectiveness evaluation of alternatives.

VARIABILITY IN LIFE CYCLE COST METHODS

As discussed above, life cycle cost is defined as the total of all relevant costs associated with a project incurred over the life of the project.

TABLE B-2. AIRCRAFT COST ELEMENT STRUCTURE

100 Research and Development

200 Investment

- 201 System Investment
- 202 Support Investment
  - 202.1 Support Equipment
  - 202.2 Training Equipment and Services
  - 202.3 Documentation
  - 202.4 Initial Spares and Repair Parts
  - 202.5 Spare Engines
  - 202.6 Facilities (Non-production)
  - 202.7 War Reserve Materiel
    - 202.7.1 Spares
    - 202.7.2 Repair Parts
    - 202.7.3 Munitions
    - 202.7.4 Missiles
    - 202.7.5 Sonobuoys
    - 202.7.6 Tanks, Racks, Adapters & Pylons

300 Operating and Support

- 301 Deployed Unit Operations
  - 301.1 Aircrews
  - 301.2 Command Staff
  - 301.3 POL
  - 301.4 Security
  - 301.5 Other Deployed Manpower
  - 301.6 Personnel Support
- 302 Below Depot Maintenance
  - 302.1 Aircraft Maintenance Manpower
  - 302.2 Ordnance Maintenance Manpower
  - 302.3 Maintenance Materiel
  - 302.4 Personnel Support

300 Operating and Support (Continued)

- 303 Installations Support
  - 303.1 Base Operating Support
  - 303.2 Real Property Maintenance
  - 303.3 Personnel Support
- 304 Depot Maintenance
  - 304.1 Manpower
  - 304.2 Material
- 305 Depot Supply
  - 305.1 Materiel Distribution
  - 305.2 Materiel Management
  - 305.3 Technical Support
- 306 Second Destination Transportation
- 307 Personnel Support and Training
  - 307.1 Individual Training
  - 307.2 Health Care
  - 307.3 Personnel Activities
  - 307.4 Personnel Support
- 308 Sustaining Investments
  - 308 1 Replenishment Spares
  - 308.2 Modifications
  - 308.3 Replenishment Ground Support Equipment
  - 308.4 Training Ordnance
    - 308.4.1 Munitions
    - 308.4.2 Missiles

Included in the definition are R&D, investment, and operating and support costs.

Although the above definition seems straighforward, there is room for a great deal of variation in the application of the estimation procedure and in the values of individual parameters. The methods used in deriving major system LCC estimates for DSARC review are well-defined in the CAIG guidelines. However, life cycle cost is a generic term and the concept is used for a variety of other purposes. One other common use of LCC is in financial analyses to evaluate and rank investment alternatives. Most energy conservation programs, especially those associated with installations, are usually viewed as investment decisions because they require a trade-off between current investment and future reductions in expenditures for fuel. Therefore, some form of LCC is normally used in the evaluation of conservation programs. At the present time however, there is no agreement on one technique or one set of parameters to generate LCC estimates for evaluating energy conservation programs. Table B-3 shows a sampling of different LCC methods and parameters used in various government program analyses.

As shown in the table, cash flows may or may not be discounted to their present values; the appropriate discount rate, when this approach is used, varies. OMB has directed that all government projects be discounted at a 10% annual rate except real property which is to be discounted at 7%. Recently DOE set the discount rate at 7.7% for the oil backout programs under the Fuel Use Act. (The DoD "FAST"[1] program is part of this initiative). In some cases, cash flows are not discounted at all, which amounts to using a 0% discount rate.

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[1]Federal Agencies Fuel Substitution Task.

TABLE B-3. VARIATIONS IN LCC APPLICATION

TYPE OF PROGRAM REVIEW	TIME PERIOD COVERED	DISCOUNTING	TREATMENT OF INFLATION	"SOCIAL PREMIUM" OR OTHER EXTERNAL COSTS	RESULTING ESTIMATES
Major Systems (CAIG/DSARC)	Life Cycle or 20 Years	No	Uses Constant Dollars	No	- Total Life Cycle Cost
Major Systems (PPBS)	5-Year FYDP Period (Except KC-135 Reengine)	No (KC-135RE uses 10%)	Uses Then-Year Dollars	No	- FYDP Dollars (KC-135RE calculates payback)
DoD Energy Conservation Programs (PPBS)	Life Cycle	Yes (10%)	Uses Constant Dollars	No	- Payback Period - Petroleum Offset
DOE Proposed Rules[1]	35 Years or Life Cycle	Yes (7.7%)	Uses Constant Dollars	Yes $1 Social Premium on Cost of Crude	- Payback Period - Return on Investment - Petroleum Offset

[1]These rules are to apply to all "oil backout" programs called for in the 1978 Fuel Use Act. Similar rules will probably be applied to federal agency "oil backout" programs such as DoD's FAST initiatives.

Cash flows may be in uninflated dollars or in inflated dollars (i.e., "constant" dollars or "then year" dollars). If inflation is included, the estimated future inflation rate may be tied to projections of individual elements within budget appropriation accounts, or to a number of U.S. economic indices, such as the Consumer Price Index (CPI), the GNP deflator or the Wholesale Price Index(WPI).

Cost escalation factors are especially important for projecting costs when the cost of an item or a service is expected to increase at a rate different from the general rate of inflation. In this case, the escalation factor may be tied to a published index or may be derived specifically for the commodity in question. Of particular interest is the fuel price escalation factor. The various energy studies mentioned in this report have used annual fuel price escalation factors ranging from 0% to 10% above the rate of inflation (i.e., "real" growth rate). When escalation rates are required, most DoD studies use the set of appropriation-related price deflators provided by the OASD(C) as part of their periodic budget guidance instructions. Fuel was included as part of the overall O&M appropriation price deflators until recently. Starting with the July 1980 "FY1981 Revised and FY1982 Budget Estimate Guidance," separate price escalation indices are provided for fuel and for O&M, excluding fuel.

An anomaly which appeared in the DOE regulations governing the evaluation procedures for the oil backout program, was the addition of a "social premium" to the life cycle cost of fuel. The goal of the premium is to force utilities and major fuel burning installations to build into their decision criteria, some of society's cost of continuing to burn imported oil. In the future, this same concept may be required for the DoD FAST program evaluation methodology. However, whether this same concept will or should be used for program evaluation practices associated with the PPBS or DSARC process is unclear.

Some of the important variations in LCC methods arise because the analyses are being used for different purposes. For example, the costs examined by the DSARC and the CAIG do not include inflation (i.e., the costs are in constant dollars), and are not discounted. This is felt to be appropriate because the DSARC process is not primarily concerned with determining the financial attractiveness of individual projects, but is concerned with examining trade-offs among alternative means of satisfying a military requirement. As long as all options are costed on the same basis, the cost-effectiveness concept is assumed to be valid.

DoDI 7041.3 is concerned with economic analysis and program evaluation. This instruction is oriented toward determining the best (economically efficient) allocation of scarce resources. LCC using discounted cash flows is one of several methods suggested for use in cost-benefit analysis, sensitivity analysis and risk/uncertainty analysis. DoDI 7041.3 also specifies some of the parameters to be used in economic analyses but is somewhat confusing in this regard. For example, while it recommends a 10% discount rate for "real dollars" in one section, it also seems to set a 7% discount rate plus 3% inflation in another section.

Life cycle costing can be adapted to many purposes, but must be approached with special care as future levels of costs, inflation and other parameters increase in uncertainty. "Sensitivity analysis" is a means of determining the effects of changes in the estimates of key parameters. By this means it is possible to identify the critical variables in an analysis, and to draw attention to the impact of changes or errors in predicting these variables.

In summary, life cycle costing is a widely-used method in weapon system costing, and financial and economic analysis. The approaches used in the various applications are significantly different. As energy efficiency options are considered more frequently in new weapon systems, the problem of what LCC methodology or mix of methodologies should be used will become more urgent. Further, because future price escalation, especially fuel, is so uncertain and has potentially large impacts, sensitivity analyses should become a standard LCC practice.

SUPPORT ENERGY IN LIFE CYCLE COST

Energy costs are most visible in the Operation and Support portion of the life of a system. It is important that O&S estimates be made early in the acquisition process to support system trade-off studies. The Integrated Logistics Support (ILS) plan identifies the necessary activities, equipment and manpower needed to support a system. The following ILS elements are identified in DoDD 5000.39.

- the maintenance plan
- manpower and personnel
- supply support
- support and test equipment
- training and training devices
- technical data
- computer resources support
- packaging, handling, storage and transportation
- facilities

Four elements (supply support; training and training devices; packaging, handling, storage and transportation; and facilities) contain subelements directly related to energy. The remaining sections discuss where energy typically enters into these four elements of the ILS plan.

Supply Support

The supply support element provides essential information regarding the provisioning, distribution and replenishment of spare parts and of special supplies, including fuel.

Based upon estimates of the intended deployment and use of the evolving weapon system, the supply support section allows the comparison of future support needs with existing capability. Where energy is an important support commodity, energy support capabilities and requirements should be included. By attaching dollar values to the projected requirements, the incremental burden on energy supply support implied by the new system can be estimated.

Training and Training Devices

Analysis under this element provides data on training requirements for both operation and support. In recent years, the increasing cost of training through actual use of weapons systems helped stimulate the development of sophisticated training simulators. These devices can be used to replace certain types of training activity in the actual system.

As the cost of energy continues to rise, simulators represent an increasingly attractive option to offset training in energy intensive systems. The analysis under this element should provide an estimate of training needs and a variety of ways to meet these needs. Training devices in the form of simulators or other aids should be identified and evaluated in this section of the analysis in terms of training effectiveness, cost, and potential energy savings.

Packaging, Handling, Storage, and Transportation (PHST)

PHST analysis also provides information on whether existing support systems can accommodate the requirements of the new system. For example, if the new system uses more fuel, additional storage may be required or a more extensive transportation system may be needed.

Facilities

Facilities analysis ensures that all facilities required for the operation and support of a system are identified, programmed, and available. Energy management under this element will rely heavily upon supply support and PHST analyses for input data. There is certain to be some overlap between PHST and facilities analyses (e.g. transporation management of petroleum would normally take into account pipelines and pumping stations requirements).

The facility analysis should identify and evaluate special energy requirements, including utility power needs, and compare them to existing facility capability. Feedback allows for alteration to either the weapon support concept or the facilities program to bring requirements and capabilities into balance.

APPENDIX C

FUEL PRICE FORECASTING BIASES

INTRODUCTION

Since 1973 the market price of crude oil has increased 380% in real (constant) dollars. This price increase represents about a 25% compound annual growth rate for the past seven years. The real price of jet fuel has increased slightly faster at a 27% annual rate, so that the cost of fuel is now a major portion of the hourly operating cost for most airplanes in the Air Force fleet.

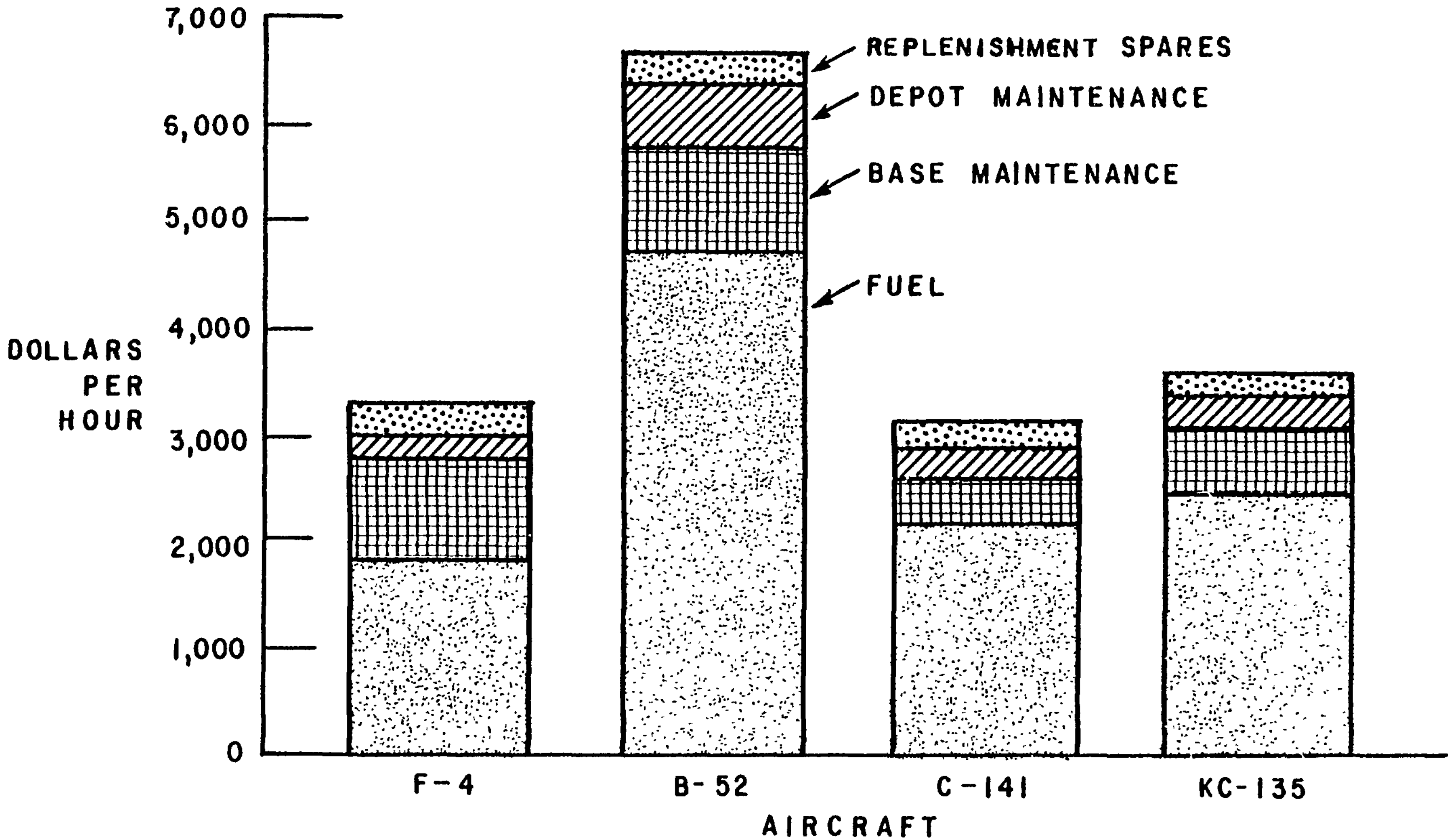
Four aircraft, the C-141, the B-52, the F-4 and the KC-135, account for over half of the jet fuel consumed by the Air Force. Figure C-1 shows a breakdown of the cost per flying hour for these four aircraft, and Figure C-2 shows fuel as a percent of cost per flying hour. Fuel is approximately 70% of the direct cost of flying each of these aircraft.

Since the OPEC embargo on crude shipments in late 1973, the price of petroleum and petroleum products has generally increased at a more rapid rate than many of the price indices commonly used to measure inflation. From 1973-1980, the consumer price index grew at an average annual rate of 9.1%, the Wholesale Price Index grew at 10.9% per year and the price of jet fuel increased at a 27% annual rate. An accurate forecast of the future trend in fuel prices would therefore be extremely valuable for projecting future operating costs of the various aircraft currently in the fleet, and also for purposes of evaluating various aircraft fuel conservation opportunities. This is particularly important now that fuel accounts for over 50% of operating cost for nearly all aircraft.

FIGURE C-1

COST PER FLYING HOUR

FY 1981

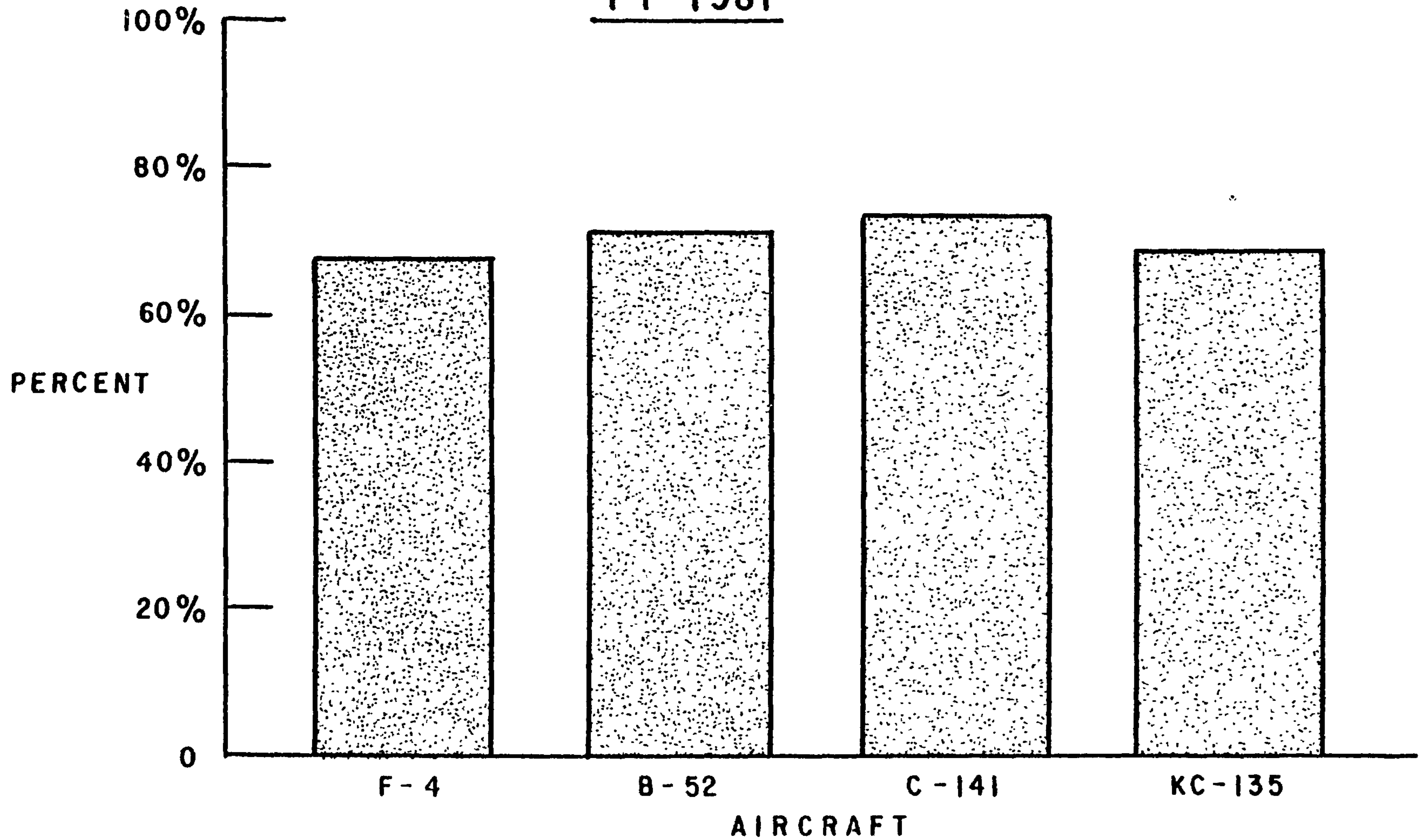


SOURCE: "USAF SUMMARY", APRIL 1980, LIFE CYCLE COST FACTORS.

FIGURE C-2

FUEL AS A PERCENTAGE OF TOTAL COST PER FLYING HOUR

FY 1981



SOURCE "USAF SUMMARY," APRIL 1980, LIFE CYCLE COST FACTORS.

PAST PRICE PROJECTIONS AND THE DIRECTION OF ERRORS

Several price forecasts, published since 1974 were reviewed to see how accurately crude prices were predicted. Table C-1 shows the predicted price of crude for 1980 in 1980 dollars compared to the actual price of domestic uncontrolled crude which sold for $32 to $39 in 1980. All the forecasts were optimistic about future prices. Both Houthakker forecasts were also accompanied by a prediction that at the high end of the price range, the U.S. would become a net exporter of oil.

TABLE C-1. FORECASTS OF CRUDE OIL MARKET PRICES

Projector	Year of Study	Projected Price in 1980 (1980 $)
MIT Energy Lab	1974	$11.40 - $14.70
PIES - DOE	1974	$11.40 - $18.00
Houthakker-Harvard	1973-74	$ 6.00 - $15.50
Houthakker-Harvard	1976	$13.20 - $35.00
RAND Corporation "Very Large Airplanes"	1973-74	$20.00
RAND Corporation "Technological Modifications"	1976	$20.00 - $25.75
Oak Ridge National Lab	1977	$21.00
Actual Price of Uncontrolled Crude Oil - April	1980	$32.00 - $39.00

Table C-2 summarizes the annual percentage growth rates for crude prices implied by the forecasts shown in Table C-1. Some recent forecasts from 1980 are also included. Econometric models and human forecasters rely on historical data to develop forecasts. Since the period 1950-1970 was characterized by constant or declining real prices for petroleum and petroleum products, it may not have seemed unreasonable for forecasters to project fairly stable prices for the future. It is interesting to examine the more recent forecasts

TABLE C-2. FORECASTS OF OIL PRICE GROWTH RATES

Forecaster	Year of Forecast	Real Growth Rate (%/Year)
MIT	1974	0
DOE	1974	0
RAND	1974	0
RAND	1976	0-4.3
Oak Ridge Nat'l Lab	1977	1.2
MIT	1977	2
EIA	1980	1-3
DRI	1980	3
Wharton	1980	2-4
OASD(C)	1980	0
Actual from 1970-1980		15

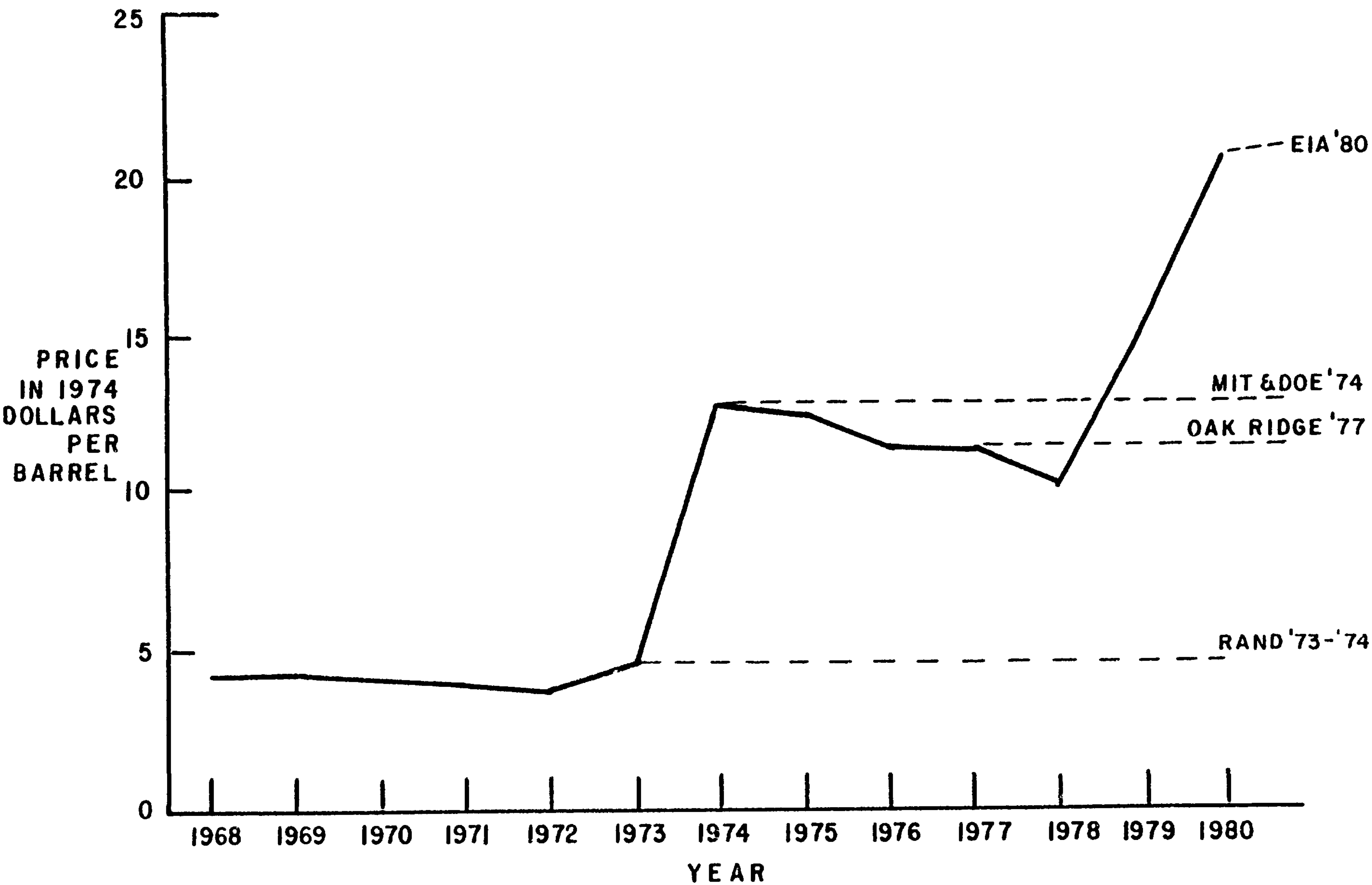
in Table C-2 to see the effects of a decade of unstable supply and rapidly increasing prices. These include DOE's Energy Information Agency (EIA) published in April 1980, one by Data Resources Inc. (DRI) for Winter 1980 and the last by Wharton Econometric Forecasting Associates, Inc., also published in April 1980.

All the recent forecasts continue to project very low real price increases, and the EIA low scenario projects constant real prices. The "best guess" according to these forecasts is that crude prices will grow at a modest rate of 2-3% per year after 1985.

Figure C-3 graphically compares the actual price of crude to the prices predicted by some of the studies from Table C-1. The lowest price prediction was that crude would cost $6.00 per barrel in 1980, a figure which is less than 20% of the current cost. The growth rates predicted in 1980 follow past predictions although few forecasters are currently predicting no real growth in prices.

FIGURE C-3

REAL CRUDE PRICE AND SELECTED PREDICTIONS



The Department of Defense predicts fuel cost escalation factors for programming and budgeting purposes. Table C-3 shows recent DoD projections.

TABLE C-3. DoD ESCALATION FACTORS IN PERCENT

FY	GNP Deflator[1]	Fuel[2]	Effective Rate for Fuel
80-81	8.5%	30.7%	22.2%
81-82	8.5	9.1	0.6
83-84	8.4	8.0	(0.4)
84-85	7.9	7.2	(0.5)
85-86	7.7	6.2	(1.5)

[1]Taken from "USAF Summary," April 1980.

[2]Memo from ASD(Controller), July 1980.

The escalation factor for fuel is within one or two percent of the predicted rate of inflation from FY 1981 through FY 1986. The factors also imply that the real price of fuel is expected to decline somewhat from 1983-86.

During the past seven years, there has been a consistent tendency to seriously underestimate future fuel prices. To the extent that decision makers continue to use "poor" price projections, or projections which are very uncertain, their investment decisions are likely to be in error.

DID FUEL FORECAST ERRORS IMPACT ACQUISITION DECISIONS?

TWO CASE STUDIES

In 1974 the RAND Corporation performed a Phase 0 study which investigated a variety of very large aircraft concepts for the next generation strategic lift mission. A wide range of propulsion concepts and alternative fuels were considered including synthetic jet fuel, liquid methane, liquid hydrogen and various nuclear concepts. As part of the study, life cycle cost estimates were made of equal capability fleets of each aircraft type to help judge their relative cost-effectiveness.

Figure C-4 shows the life cycle cost estimates for three of the non-nuclear alternatives. The acquisition costs for the three alternatives were found to be within about 25% of one another, with the hydrogen airplane the least costly to acquire, primarily due to its slightly lighter airframe weight. The fuel costs for 20 years of operation show the largest variation among the aircraft, varying over a factor of three. The cost-effectiveness conclusions therefore would be expected to be quite sensitive to the assumptions about fuel prices. The study assumed a constant real price for jet fuel from 1974 through 2000; this means the 1980 price of jet fuel in constant 1974 dollars was projected to be about 35 cents per gallon, which is about half the actual price of 65 cents per gallon. While other elements of the LCC estimates may have also changed significantly over the past five years, it does seem clear that the projections of fuel cost could have had an important impact on the study findings and conclusions.

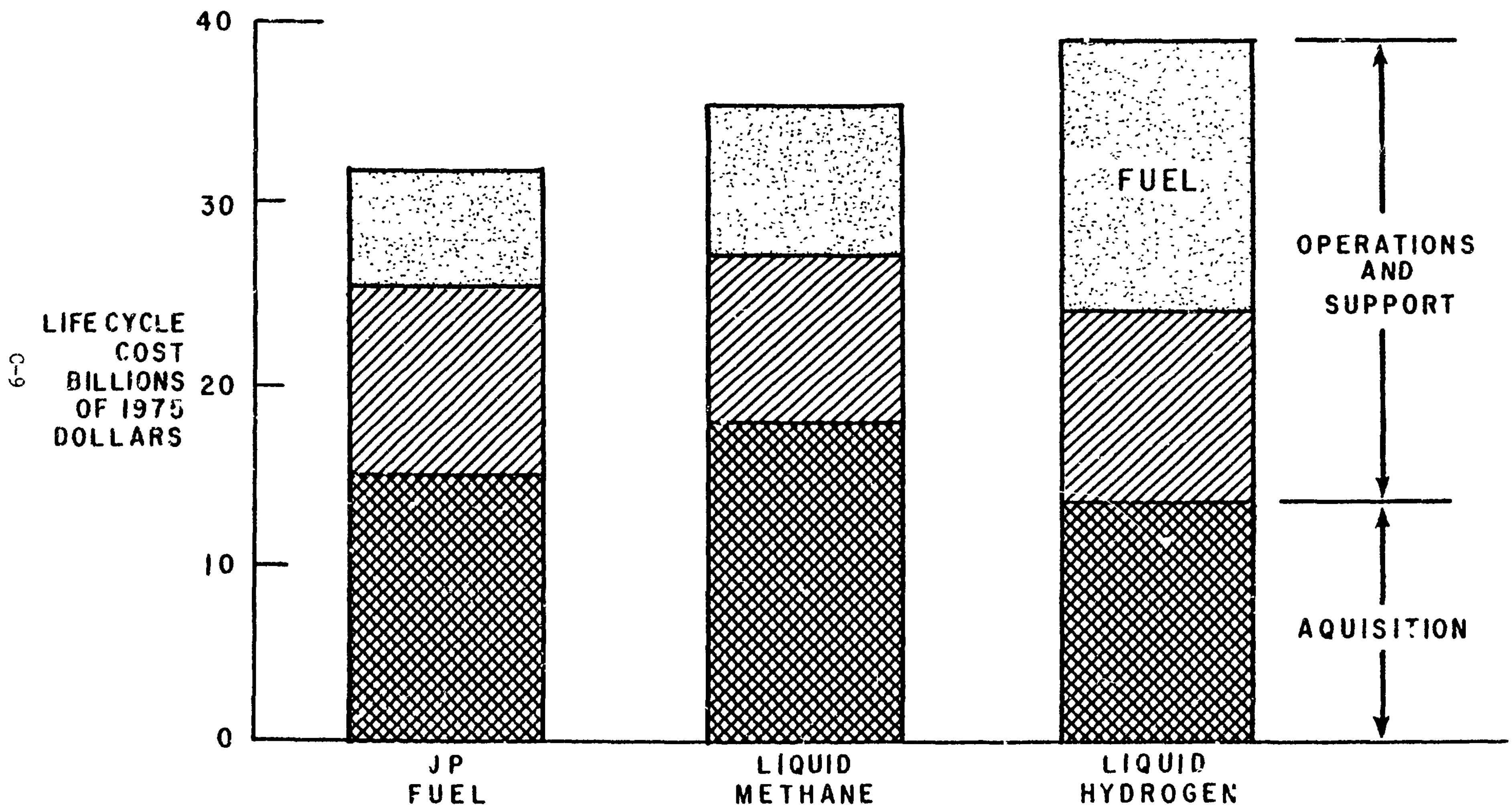
A second study, done in 1976, examined the cost effectiveness of various engine retrofits and airframe modifications to USAF aircraft.

The study looked at the possiblity of improving fuel efficiency by retrofitting new engines and making various structural modifications to the C-141, the KC-135, the B-52 and the F-4. These four aircraft were chosen because they are the largest consumers of fuel in the Air Force. The modification options considered in the study are shown in Table C-3. The proposed changes were judged to be not cost-effective, or of marginal value, given the assumptions on fuel prices. Again, the conclusions were based on an assumption of constant real prices for jet fuel through 2000. (The study presented sensitivity analyses assuming a 4.3% annual increase in real fuel prices, but did not use the results in drawing the basic conclusions.)

FIGURE C-4

COMPARISON OF LARGE AIRCRAFT LIFE CYCLE COST

TYPICAL PHASE 0 ANALYSIS



SOURCE: RAND CORPORATION, "AN EVALUATION OF VERY LARGE AIRPLANES AND ALTERNATIVE FUELS", DECEMBER 1976

TABLE C-3. SAMPLE OF TECHNOLOGICAL MODIFICATIONS FROM 1976 RAND STUDY

Aircraft	Modification	Results
C-141	Replace 4 TF33 Engines with 2 TF39 Engines	Reduce Fuel Consumption 25%
B-52	Replace 8 J57 Engines with 4 TF-39 Engines	Reduce Fuel Consumption 33%
C-141	Improve Design of Wing Fillets	Reduce Drag 5%
C-141	Remove Vortex Generators	Reduce Drag 3%
KC-130	Afterbody Modifications	Reduce Drag 9%
KC-135, C-141, C-130, B-52	Install Winglets	Reduce Drag 5-10%

The two RAND studies contain two elements of error in the price forecasts which understate life cycle costs for fuel. The projected growth rates for the price of fuel from the date of the study to the initial operational dates of the modified aircraft grossly understate the actual increases that have occurred; and the projected starting price is about half the current actual price in constant dollars. Thus, even if one expected fuel prices to stabilize for the rest of the century, the LCC fuel estimates are understated by about a factor of 2. Secondly, if any real growth in fuel price should occur during the next 20 years of operating the modified aircraft, the LCC error could be even larger. For example, if fuel prices continued to grow beyond 1980 at an average of 10% per year, the LCC estimates for 20 years of fuel at a constant price would be low by a factor of about 7.5.

SUMMARY AND CONCLUSIONS

For the past seven years the price of crude oil has grown at an annual rate of 25%. The cost of jet fuel has increased at a slightly higher rate so that fuel now accounts for over 50% of the direct O&M costs for most aircraft. As the DoD makes acquisitions of new aircraft and other weapons systems, or considers energy saving modifications to current systems, the future price of fuel is an increasingly important part of the life cycle cost.

Several older forecasts of prices were reviewed and all forecasted prices were found to be significantly lower than the current price of crude and jet fuel. Several recent forecasts were also reviewed. These forecasts continued to project very low rates of increase for the price of fuel.

These optimistic forecasts of future energy prices have biased and continue to bias decisions away from conservation projects, and toward continued dependence on petroleum based fuels. As long as the price of petroleum is assumed to remain stable, many conservation projects will not appear cost-effective and will be delayed. At some price for petroleum, of course, these projects will eventually become cost-effective. Analyses can be performed to determine at what fuel growth rate and what fuel price conservation projects become acceptable. Such calculations should become an important input to the energy conservation program decision process.

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Defense energy has become a major budgetary, operational and policy issue as a result of the rapidly escalating price of oil and growing U.S. dependence on uncertain overseas oil supplies.

The Department of Defense (DoD) has concentrated on conserving energy through reductions in operations and through programs to reduce consumption at installations. In the long run, the DoD has an opportunity to significantly

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increase energy conservation by acquiring more energy-efficient major weapon systems.

This report reviews the process by which major weapon systems are acquired, and recommends steps that should be taken to better identify and evaluate opportunities for improving future system's energy efficiency.